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VOL. XV JANUARY 1961 NO. 1

PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

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A Collection of Porifera from Northern New Zealand

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DIPTIMAN CHAKRAVARTI and RONALD EISLER
Strontium–90 and Gross Beta Activity in Rongelap Coconut Crabs

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SMITHSONIAN INSTITUTION MAR 23 1961

A Taxonomic Study of the Indigenous Hawaiian Species of the Genus *Hibiscus* (Malvaceae)

Sister MARGARET JAMES ROE[1]

THE GENUS *Hibiscus* is a member of the Malvaceae, a family of 80 or more genera distributed throughout the world except in frigid regions. Many abound in the tropics and subtropics, where they are important as ornamental and commercial plants.

Since *Hibiscus* hybridization was first successfully accomplished in Hawaii in 1872 by Governor Archibald Cleghorn of Oahu, a growing interest in the genus has prevailed not only in Hawaii, where the legislature has designated one of the species as the official flower, but also throughout global tropical and subtropical regions. Horticulturists striving to secure desirable varieties have introduced to Hawaii many new species, subspecies, and forms (Nakasone, 1953). The popularity of the genus has stimulated numerous amateur hybridizers to produce thousands of complex hybrids whose parentage is now impossible to trace. The attractiveness of these exquisite cultivars has encouraged and nourished the organization of several societies to foster such hybridization.

Little attention, however, has been given to the indigenous members of the genus, several of which have been useful in the production of these hybrids. Heretofore, no single comprehensive work has been done on the native members of the genus. Individual descriptions have appeared in print as far back in 1819. Hillebrand (1888) and Rock (1913) both included several *Hibiscus* species in their Floras. It is the purpose of this work to record as complete as possible an investigation of the native species, varieties, and forms, resolving the groups of the indigenous *Hibiscus* populations into taxonomically recognizable groups.

This study could neither have been undertaken nor accomplished without the help of friends who gave time, knowledge, and encouragement. I am primarily indebted to Dr. Harold St. John, former Professor of Botany at the University of Hawaii, for introducing me to the problem. I am indebted to Mr. Irwin Lane for supervising the taxonomic and nomenclatural conclusions. Dr. Joseph F. Rock also contributed many hours in discussing the problem and collecting specimens. I am indebted to Miss Marie Neal, Dr. Otto Degener, Mr. and Mrs. Colin Potter, and Messers. Paul Weissich, Donald Anderson, Albert Duvel, and Henry Wiebke for their contributions to this work. Dr. Reed C. Rollins and Dr. Robert C. Foster of the Gray Herbarium checked and reported on material there. Dr. Richard S. Cowan investigated the *Hibiscus* specimens at the Smithsonian Institution (U. S. National Museum) and sent lengthy descriptions and explanations. On the island of Kauai, Mr. George Cliff acted as guide during my stay at Waimea Canyon. Mrs. Hector Moir of Poipu, Mr. John Santos of Eleele, Mr. Stephen Au of Lihue, Mr. Ronald Harker of Hale Manu, Mr. Adam Jacinto of Kalaheo, and Mr. Solomon Malina of Kipu were instrumental in helping me with collections on Kauai.

The illustrations were made by Sister Chris-

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tina Francis of Maryknoll High School.

All herbarium specimens mentioned in this paper are deposited at the Bernice P. Bishop Museum in Honolulu, unless otherwise stated.

HISTORY OF THE GENUS *Hibiscus* IN HAWAII

The history of the indigenous Hawaiian *Hibiscus* dates back to Gaudichaud's *Hibiscus Youngianus,* which was collected on the Freycinet Expedition, 1819. He mentioned it (1826) but failed to add any details; hence it was a *nomen nudum* as published, until Hooker and Arnott furnished the description (1832). Gray (1854) described both *H. Brackenridgei* and *H. Arnottianus.* In 1888 Hillebrand added *H. Kokio* to the three published species. This was followed closely by Heller's description (1897) of the Kauai white *H. waimeae.* Hochreutiner (1900) included all members in the genus known in all parts of the world. The Hawaiian populations received treatment by him. Forbes (1912) found and named an endemic Kauai species, *H. kahilii,* which is still considered rare. From 1912 to 1930 little was done in the way of publication until Caum presented Rock's *H. Brackenridgei* var. *molokaiana;* a variety of his own, *H. Brackenridgei* var. *kauaiana;* and a variety to *H. Kokio* var. *pukoonis.* Skottsberg, on his Hawaiian Bog Survey assignment, found and described a variety and a form of *H. Arnottianus.* From that time, 1944 to 1957, no new groups were established. Degener (1957) recently raised Skottsberg's var. *punaluuensis* of *H. Arnottianus* to the level of a species, *H. punaluuensis.*

At present we recognize 15 populations of *Hibiscus* as indigenous to the Hawaiian Islands —9 species, 5 varieties, and 1 form.

DESCRIPTION OF GENERIC CHARACTERS

The genus *Hibiscus* is a large taxon whose species, hundreds in number, are restricted to the warmer regions of the world. It is polymorphic, including species that are herbaceous, shrubby, or arborescent, some of the latter attaining heights of 30 ft. or more.

Linnaeus (1754) listed *Hibiscus* under genus no. 756 and gave the fundamental description of this taxon. His original characters included double perianth; bracts 8 or more in number; calyx cup-shaped; 5 heart-shaped petals united at base; numerous filaments joined to column; anthers reniform; 5-celled ovary; divided stigma; reniform seeds.

Since this original description of Linnaeus, we have broadened our knowledge of the genus. It can be summarized in the following manner. Involucre consists of several free bracts. Calyx 5-lobed or toothed, persists with fruit. Flowers borne singly in axils, composed of 5 petals which are frequently wider toward their apices, narrowing towards base, where they usually unite with column. Flowers commonly large, showy, and of conspicuous colors. Staminal column composed of filaments which are united into hollow sheath for some distance from base; 5-toothed at apex. Filaments extend out from column at various positions, usually close to stigma. Style runs through column and terminates in 5 branches, each of which has a terminal discoid stigma. Five carpels, each containing several ovules, united into a 5-celled ovary. Capsule opens loculicidally. Seeds vary in shape from reniform to globose, with surfaces from glabrous to tomentose. Leaves variously lobed or entire, alternate, stipulate, and scarcely to distinctly palmately veined.

The genus *Hibiscus* seems closely related to the genera *Paritium* and *Abutilon. Paritium* is allied to *Hibiscus* inasmuch as both genera have involucrate calyces which are 5-lobed; also 5-style branches with capitate stigmas. The involucral bracts of *Paritium,* however, are united, whereas those of *Hibiscus* are free.

Abutilon and *Hibiscus* both have carpels with 2 or more ovules. *Abutilon* species do not have involucral bracts but have staminal columns ending in filaments.

In distinguishing the various taxa under consideration, the following characters were most valuable: bract number (5–10), calyx length (1.0–3.0 cm.), and venation of calyx and leaves. Staminal column lengths (2.0–19.0 cm.), vesture, petal shapes, position of filament extension from column, and seeds are also important differentiating characters.

KEY TO KNOWN HAWAIIAN MEMBERS OF THE GENUS *Hibiscus*

A. Corolla yellow ..... B
  B. Calyx 10-veined; petals 3.0–4.0 cm. long C
    C. Leaves deeply lobed; bracts 8–10, glabrous, terete, nonglandular; calyx glandular; petals 3.0–3.5 cm. long, ca. 2.5 cm. wide; staminal column 4.0–4.5 cm. long....2. *H. Brackenridgei*
    C. Leaves moderately lobed; bracts 7–8, hirsute, terete, nonglandular; calyx nonglandular; petals 3.0–4.0 cm. long, ca. 5.0 cm. wide; staminal column 7.0–8.0 cm. long.....
    .....5. *H. Brackenridgei* var. *mokuleiana*
  B. Calyx 5-veined; petals more than 4.0 cm. long ..... D
    D. Leaves deeply lobed; bracts 8–9, hirsute, terete, glandular; calyx nonglandular; petals ca. 5.0 cm. long, 4.3–4.5 cm. wide; staminal column 4.0–5.0 cm. long.....
    .....3. *H. Brackenridgei* var. *molokaiana*
    D. Leaves entire to shallow lobed; bracts 5, hirsute, nonterete, nonglandular; calyx glandular; petals 5.7–6.0 cm. long, 4.8–5.0 cm. wide; staminal column 2.3–2.5 cm. long.....
    .....4. *H. Brackenridgei* var. *kauaiana*
A. Corolla not yellow ..... E
  E. Corolla pink; plant densely hirsute; bracts 10–12, bifid, 1.0–1.3 cm. long, ca. 1.0 mm. wide; calyx glandular, lobes 2.3–2.5 cm. long, cleft 1.0 cm. from apex.....1. *H. Youngianus*
  E. Corolla not pink; entire plant not densely hirsute; calyx nonglandular ..... F
    F. Corolla red ..... G
      G. Calyx glabrous; petioles 2.0–4.0 cm. long; staminal column 5.5–5.7 cm. long; petals 5.5 cm. long, 3.5 cm. wide ..... H
        H. Calyx 2.8–3.0 cm. long; 1.2 cm. wide; lateral calyx nerves fused immediately below cleft.....6. *H. Kokio*
        H. Calyx 2.4–2.5 cm. long; 1.0 cm. wide; lateral calyx nerves fused 5–10 mm. below cleft.....7. *H. Kokio* var. *pukoonis*
      G. Calyx nonglabrous; petioles less than 2.0 cm. long; petals more than 5.5 cm. long, less than 3.5 cm. wide I
        I. Staminal column more than 5 cm. long; peduncles more than 1.0 cm. long..... J
          J. Calyx cleft 1.2–1.3 cm., pilose; petioles 0.5–1.8 cm. long; petals 6.5–6.7 cm. long, 2.5–3.0 cm. wide; staminal column ca. 6.0 cm. long.....8. *H. Saintjohnianus*
          J. Calyx cleft 2.0–3.0 cm., pubescent; petioles 0.3–0.8 cm. long; petals 6.0–6.5 cm. long, 1.0–1.2 cm. wide.....9. *H. kahilii*
        I. Staminal column less than 5 cm. long; peduncles less than 1.0 cm. long.....
        .....10. *H. Newhousei*
    F. Corolla white ..... K
      K. Staminal column white, leaf margin denticulate, apex rounded.....11. *H. immaculatus*
      K. Staminal column red, leaf margin entire or serrate, apex almost acute L
        L. Leaves velvety to the touch; calyx cleft 1.0–1.5 cm.; bracts 1.5–2.5 cm. long.....
        .....12. *H. waimeae*
        L. Leaves lack velvety touch; calyx cleft only 0.5 cm.; bracts 0.5–1.0 cm. long..... M
          M. Leaves 4–10 cm. long, 4–7 cm. wide, ovate to elliptical-parabolical, glabrous; petioles 0.5–2.0 cm. long, glabrous ..... N
            N. Leaves 8–10 cm. long, 5–7 cm. wide; calyx 2–3 cm. long....13. *H. Arnottianus*
            N. Leaves 4–6 cm. long, 4–5 cm. wide; calyx 1–2 cm. long.....
            .....14. *H. Arnottianus* f. *parviflora*
          M. Leaves 10–25 cm. long, 8–20 cm. wide, ovate-subcordate, pubescent; petioles 3–12 cm. long, densely puberulent.....15. *H. Arnottianus* var. *punaluuensis*

1. *Hibiscus Youngianus* Gaud. ex H. & A. Figs. 1–3

Hibiscus Youngianus Gaud. ex H. & A. Bot. Beechey Voy., p. 79. 1832.

H. furcellatus Lam. var. *Youngianus* (Gaud.) Hochr., Ann. Conserv. Jard. Geneve, p. 132. 1900.

DESCRIPTION. Stiffly erect with a paucity of pithy branches, to 3 m. high (average ca. 2.5 m.), diameter at base ca. 8 cm., hirsute and pilose throughout, lateral branches very strongly ascending, nearly parallel to the main stem. Leaves more abundant above, "Scheele green" in color (cf. Ridgway); stipules 5–6 mm. long, 0.5 mm. wide, pubescent; petioles 9–13 cm. long, scabrous; blade 10–12 cm. long, 11–12 cm. wide, wide ovate, varying from nearly entire to moderately lobed, base cordate, upper portions acutish, margins serrate-dentate, both surfaces scabrous-hispid, this more abundant on the veins; veins 5–9, palmately arranged throughout the blade. Peduncle axillary, 1.5 cm. long, 3 mm. in diameter, puberulent. Involucral bracts 10–12, 1–1.3 cm. long, ca. 1 mm. diam., terete, bifid at apex. Calyx "Scheele green" (cf. Ridgway), 2.2–2.5 cm. long, 1.5–1.8 cm. diameter at throat, hirsute, cleft 1 cm., lobes lanceolate, veins 10, prominent, gland on midvein of each lobe at the throat level. Petals "mallow purple" (cf. Ridgway), 5.8–6.5 cm. long, 4–4.5 cm. wide, tubular at base, prominently nerved, microscopic hairs on both surfaces. Staminal column dark maroon-purple, 2.0–3.0 cm. long; free filament tips extend 1–2 mm. from column, arranged in rings approximately 5 mm. apart; anthers deep purple; style inconspicuously exerted; style branches 1–2 mm. long, each terminating in a 1 mm. discoid stigma. Ovary ca. 1.0 cm. long, 8 mm. in diameter; seeds numerous, 2.8 mm. long, 2.0 mm. wide, dark brown, glabrous.

This species was first brought to our attention by Gaudichaud (1826): "...un hibiscus nouveau de la section 5 (furcaria) de M. Decandolle (h. youngiana)..." (*nomen nudum*). The first description was made in 1832 by Hooker and Arnott, who credited the species to Gaudichaud, ex Hooker and Arnott. Hillebrand (1888) included this species, as did Heller (1897). Both authors regarded it as a true indigenous species. However, in 1900, Hochreutiner monographed the genus and reduced *H. Youngianus* to a variety of *H. furcellatus* Lam., and cited specimens of the latter from Central and South America as well as from Hawaii.

I have grown the species in question for several years and I know its morphology and growth habits well. I have also obtained and observed *H. furcellatus* Lam. and find the two populations very similar. It is easy to see how Hochreutiner arrived at his conclusion. However, after examining them minutely I feel that their differences warrant the classification of them as distinct species.

Table 1 shows several important distinguishing characteristics.

Skottsberg (1926) reviewed Hochreutiner's revision and concluded that the latter's proposed close proximity of *H. Youngianus* and *H. furcellatus* was an improbable one.

A contradiction regarding locality might also be thought to exist when comparing a statement of Hillebrand's found in small print following his description of *H. Youngianus* ("In marshes and abandoned taro patches here and there on all the islands....") with a statement of Mrs. Sinclair's (1885) that the species

...was once a common flower in nearly all valleys and sheltered places; seeming to flourish equally well on both the leeward and windward sides of the islands. Now cattle and cultivation have almost exterminated the plant on the dry lee-side, but it is still frequently met with on the windward side; where, owing to the more luxuriant vegetation, many plants, which have disappeared from the leeward side, are still found. The Hauhele [*sic*] was once so plentiful in many parts that the 'aho' (thatching sticks) of the houses were made of the stems, and anyone who knows what a great quantity of 'aho' a single, old-fashioned house required, will readily see how abundant the plant must have been.

FIG. 1. *Hibiscus Youngianus* Gaud. ex H. & A. Kawainui Swamp, Kailua, Oahu. Roe no. 205. Half scale. *a*, Cross section of ovary, × 1; *b*, staminal column, × 1.

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TABLE 1

PART	*H. Youngianus*	*H. furcellatus*
Stipules	length 5–6 mm.	length 8–10 mm.
	vesture hirsute	vesture short, stellate
Leaf color	"Scheele green" (yellowish green)	"grass green" (bluish green)
Leaf shape	apex acute	acuminate
	blade roundly lobed	blade acutely cleft
Stem	puberulent, hirsute	pilose
Bracts	length 1–1.3 cm.	length 1.5–2.1 cm.
	vesture densely hispid	vesture short, stellate
	hairs 1–1.5 mm. in length	hairs microscopic
Calyx of fresh flower	sepal length 2.2–2.5 cm.	sepal length 1.7–1.8
	calyx diameter at throat 1.5–1.8 cm.	calyx diameter at throat 1.1–1.3 cm.
	densely hispid	sparsely hispid
	cleft 1 cm. from sepal apex	cleft 1.8 cm. from sepal apex
	veins raised	veins extremely raised
Petals	length 5.8–6.5 cm.	length 4–5 cm.
	width 4–4.5 cm.	width 2.5–3 cm.
	color, "mallow purple" (deep pink)	color, light "phlox purple" (pale pink)

Hillebrand is correct in stating that *H. Youngianus* is a marshland plant, for I have collected it growing in several inches of water in the central area of Kawainui Swamp, Oahu, and similarly in water at the foot of Wailua Falls, Kauai. But likewise, Mrs. Sinclair could be correct in her statement of locality, for I have recently observed it in upper Manoa on a rather dry slope, but in a rainy belt. The species, however, grows more luxuriantly and flowers continually in a wet environment. I have grown it in areas of little rainfall. It continues to grow, but much less vigorously than in swamp areas.

FIG. 2. *Hibiscus Youngianus* Gaud. ex H. & A.

Heller (1897) is incorrect in stating, "It is found only on Oahu." It has been collected on all of the major islands except Molokai, Lanai, and Niihau. (See Fig. 3.)

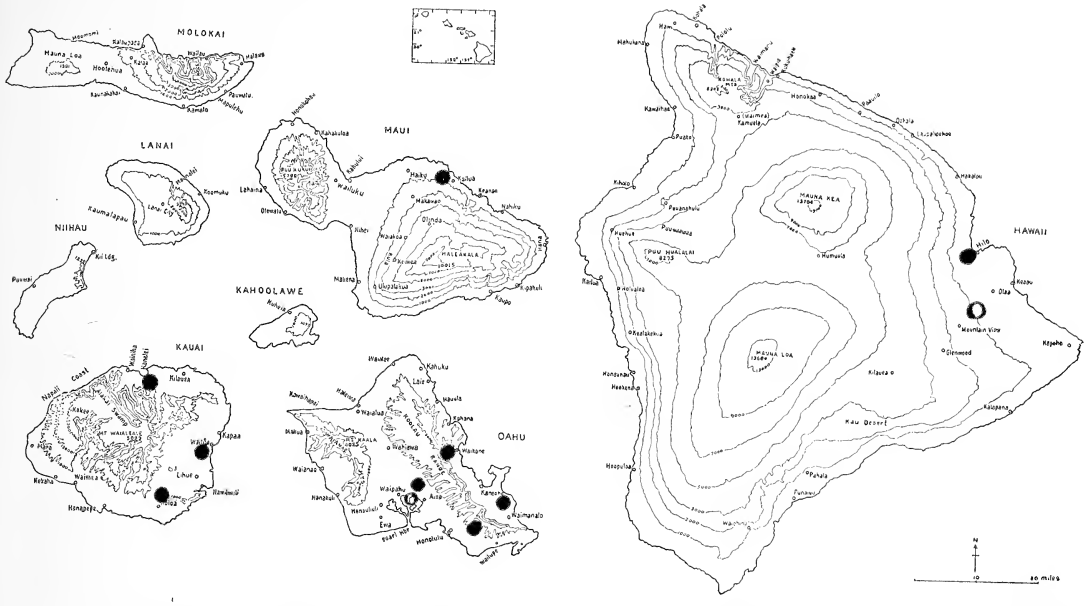
SPECIMENS EXAMINED: *Hawaii:* Rainbow Falls, May 16, 1915, *C. N. Forbes 525.H.* Lava flow near Hilo, May 17, 1915, *C. N. Forbes 545.H.*

Kauai: Hanalei, August 4, 1909, *C. N. Forbes 128.K.* Wailua Falls, October 5, 1916, *C. N. Forbes 498.K.* Wailua Falls, July 26, 1957, on the bank of the pool at the bottom of the falls, *Roe 251.* Weoweopilau Stream, on banks of stream near cane fields, altitude 500 feet, July 28, 1957, *Roe 256.*

Maui: Haleakala, October 10, 1922, *Skottsberg 793.*

Oahu: Woodlawn, Manoa, October 2, 1933, *Neal.* Waihole Valley, November 4, 1938, *Neal.* Waihole Ditch, May 1957, *Pearsall.* Kawainui Swamp, Kailua, May 4, 1930, *St. John.* Manoa about 500 yards off Woodlawn Drive, about ¼ mile west of Old Ti Slide, altitude 550 ft., October 31, 1956, *Roe 203.* Kawainui Swamp, Kailua; plant growing in water, December 31, 1956, *Roe 205.*

Hawaiian Islands: H. Mann & W. T. Brigham 598. Onekahakale Beach, August 15, 1936. *V. O. Fosberg 64.*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KILAUEA
Kau Desert
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Kapaa
Lihue
Waialua
Kaneohe
Pearl Harbor
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Mauna Loa
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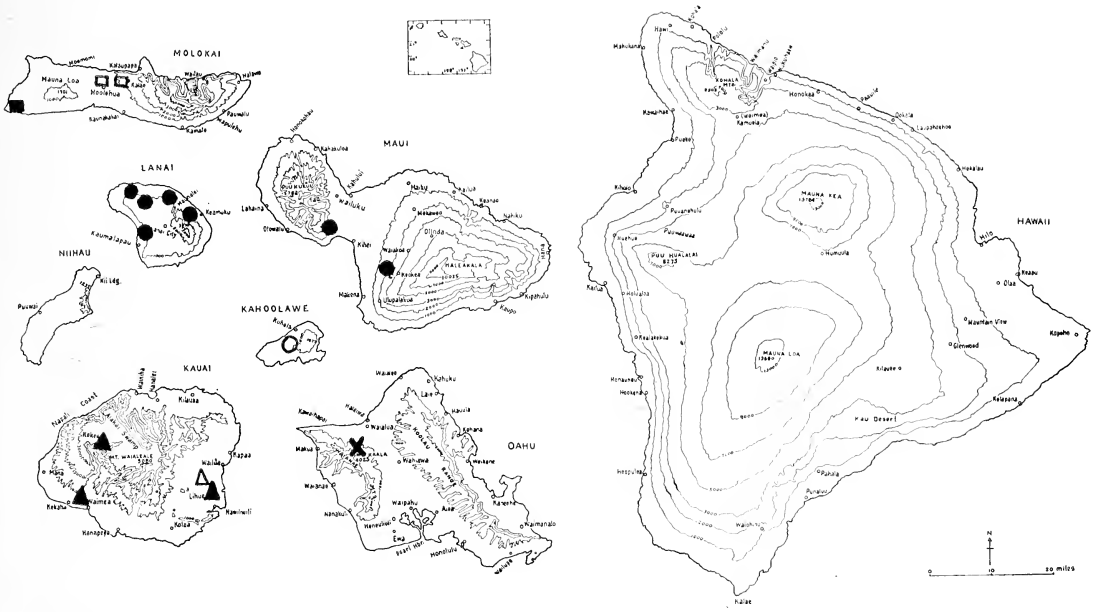
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Kamuela
Puuwai
Kaumalapau
Manele
Lanai City
Kaumakani
Waimea
Kekaha
Kalaheo
Lihue
Kapaa
Hanamaulu
Kilauea
Princeville
Hanalei
Waimea
Kekaha
Hanapepe
Koloa
Poipu

ern Molokai, back of Kalaeokalaau in 1910, and collected there by him again in 1920. Cuttings were made and several plants were cultivated at the "Rockery" on the University of Hawaii campus. I have since tried to find traces of this variety again on Molokai but with little success. Henry Wiebke, principal of Holomua School, Hoolehua, told me that he collected it in the late 1920's but cannot find it now. Mrs. Cooke, Molokai resident, is anxious to preserve the variety also but has been unable to locate it. (She did have several plants growing along her driveway until a few years ago.)

4. *Hibiscus Brackenridgei* var. *kauaiana* Caum
Figs. 5, 7

Hibiscus Brackenridgei Gray var. *kauaiana* Caum. New Hawaiian Plants, Bishop Mus. Occ. Pap. 9(5): 5–6, pl. 4. 1930.

DESCRIPTION: Erect to spreading shrub to 1 m. Leaves dentate, cordate, 8 cm. long, 8 cm. wide, shallowly 3-lobed, densely pubescent on both surfaces. Petioles 4–5 cm. long, pubescent. Stipules setaceous. Peduncles 1.5 cm. long; 5 bracts, 3 cm. long, 8 mm. wide, halberd-shaped, not terete, not glanduliferous, hirsute with short hair. Calyx 2.5 cm. long, triangular lobes each with an oblong gland at the base of a thick midrib, hirsute with colorless hairs, glabrous on inner surface. Corolla 12 cm. in diameter, "lemon yellow" to "canary yellow," dark "reddish-purple" throat 3 cm. deep. Petals spreading, slightly reflexed at tips, 6 cm. long, 5 cm. wide, 14–16 nerved. Ovary pubescent with colorless hairs. Staminal column 3 cm. long, irregularly antheriferous for entire length, glabrous; lower filaments 5 mm. long, upper ones shorter. Style branches 2 mm. long, hirsute. Stigmas capitate, depressed, deep "reddish-purple." Capsule ovoid, acute at tip, 2.5 cm. high, 17 mm. maximum diameter. Seeds broad-reniform, 3 mm. long, hirsute with short gray hair.

FIG. 6. *Hibiscus Brackenridgei* var. *molokaiana* Rock. (Picture taken by Joseph F. Rock.)

HOLOTYPE: E. L. Caum. From plants in cultivation at 1420 Piikoi Street, Honolulu.

SPECIMENS EXAMINED: *Kauai:* Waiawa, April 1919, *Rock 16038*; also *Rock 17141.* "V. Knudsen's home," 1919, *Rock.* Waimea, near Hale Manu, altitude 3300 feet, July 28, 1957, *Roe 253, 254, 257.*

Oahu: 1420 Piikoi Street, cuttings from original type plant, *Caum.* 1508 Alexander Street, cuttings from Hale Manu plant, *Roe 307.*

H. Brackenridgei var. *kauaiana* is quite uncommon. I located it at Hale Manu near Kokee, but there were only three plants of it at this location. In tracing its origin to the Waimea area I found cuttings had been brought up there from a wild plant at a lower elevation. The original plant has not been found.

Several collectors, including Rock, have mentioned two distinct varieties of *H. Brackenridgei* on Kauai, one more arborescent than var. *kauaiana* Caum. In 1957 I made cuttings of a plant not in flower on Kauai that I felt had different growth habits. This plant is in cultivation now, with one also thought to be of this arborescent Kauai variety, given to me in July, 1958, by Rock. They have not flowered, so at present taxonomic judgment cannot be passed on their distinctness.

5. ***Hibiscus Brackenridgei*** var. ***mokuleiana*** nov. var.
Figs. 5, 8

DESCRIPTION: Arbor 10–12 m. alta basi 20–25 cm. diametro. Stipulis 1–2 cm. longis pilosis. Petiolo 6–9 cm. longo piloso, lamina 9–11 cm.

longa 8–10 cm. lata, 5-lobatis sinibus angustis, basi cordate, margine serrata, nervis palmatis. Pedunculo 1.5 cm. longo, piloso echinatoque. Bracteis 7–8, 2–3 cm. longis subulatis teretibus, nonglanduliferibus, hispidis. Calyce campanulata 3–4 cm. longa, 1.5–1.8 cm. lata lobis eglanduliferis inter lobos 1.5 cm. partitis extus hispida deci-nervata. Corolla citrea, tubo atro purpureo. Petalis 8–10 cm. longis 5–8 cm. latis extus pubescentis, 12–16 nervatis. Ovario 0.8–1.0 cm. longo, 5 cm. lato, dense albo-villoso. Columna staminea 7–8 cm. longa puberula extremitates filamentorum liberae verticillatae per totam columnam longitudinem exsertae, ramuli styli 2 mm. longi tomentosi, stigmis capitatis compressis. Capsula 2.0–2.5 cm. longa lignea pilosa. Seminibus angulosis hirsutis.

Tree 10–12 m. tall, 20–25 cm. in diameter at base. Stipules 1–2 cm. long, pilose. Petiole 6–9 cm. long, pilose. Leaf 9–11 cm. long, 8–10 cm. wide, 5-lobed with narrow sinuses, base cordate, apex acute, margin serrate, palmately veined. Peduncle 1.5 cm. long, pilose and bristly; bracts 7–8, 2–3 cm. long, subulate, terete, nonglanduliferous, hirsute hairs 2–3 mm. long; calyx campanulate, 3–4 cm. long, 1.5–1.8 cm. wide, lobes nonglanduliferous, cleft 1.5 cm. from apex, hirsute with colorless hair on outer surface, inner surface glabrous, 10-veined. Corolla "lemon yellow," tube "deep purple." Petals 8–10 cm. long, 5–8 cm. wide, pubescent on outer surface, 12–16-veined. Ovary 0.8–1.0 cm. long, .5 cm. in diameter, densely pubescent with white villous hairs. Staminal column 7–8 cm. long, puberulent, free filament tips extend in rings the entire length of column. Style branches 2 mm. long, tomentose. Stigmas capitate, depressed. Capsule 2.0–2.5 cm. long, woody, pilose. Seeds angulate, hirsute.

HOLOTYPE: *Roe 210.* Second gulch east of Mt. Kaala, Oahu. Altitude 600 feet; about 40 ft. up a stream bank.

SPECIMENS EXAMINED: *Oahu:* Gulch north of middle ridge between Puu Kamaokanui and Puu Pane, Jan. 10, 1932, *O. Degener 8961,* also *8962, 8963.* First small gulch northwest of Puu Pane Peak, April 2, 1950, *O. Degener 20943.* Kapalama Heights, Kamehameha Girls School (in cultivation) March 21, 1932, *A. F. Judd.* Waianae Mountains, near Mokuleia Forest Reserve, near valley on slope of Puu Iki, altitude 500 ft., May 13, 1941, *Karl Korte.* Waianae Mountains, Mokaleha Cliffs, May 1917, *Rock 12986.* Waianae Mountains, Mokuleia area, February 16, 1957, *Roe 219.* In cultivation on Alexander Street, Honolulu, April 9, 1958, *Roe 269.* Waianae Mountains, Mokuleia, second gulch east of Puu Kaupakuhale, northeast of Puu Kaala, May 14, 1933, *St. John 13184.*

FIG. 7. *Hibiscus Brackenridgei* var. *kauaiana* Caum.

There exists on Oahu in the Mokuleia section a population of the species that shows distinct differences from the original Maui plants. This Mokuleia variety has been collected by Rock, A. F. Judd, Potter, St. John, Degener, K. H. Korte, and others. Degener made a notation on his plants nos. 8961, 8962, 8963 from this area, stating that this was a variety of *H. Brackenridgei* Gray. Rock recently gave me a photo of a tree of this taxon and on the back of the picture he had written "*Hibiscus Brackenridgei* var., 1917. J. F. Rock, Makaleha Cliffs, No. 12, 986."

This variety takes the form of an erect tree (reaching 30 ft.). It differs from the species in its leaf shape, size, and pubescence, and in bract number and surface lengths of petiole, stipules, calyx, petals, and column.

SUMMARY OF DISTINGUISHING CHARACTERS OF *H. Brackenridgei* POPULATIONS

Upon observation of the *H. Brackenridgei* populations, it is evident that four groups are distinct. Var. *molokaiana* stands apart for its long petioles and small, deeply lobed leaves; var. *kauaiana* has larger leaves, entire to shallow lobed; and var. *mokuleiana* is definitely arborescent, bearing larger flowers. Table 2 compares the differentiating characters.

6. *Hibiscus Kokio* Hbd.
Figs. 9–11

Hibiscus Kokio Hillebrand. Flora of the Hawaiian Islands, p. 173. 1873.
H. Boryanus Hook & Arn. Bot. Beechey Voy., p. 79. 1841.
H. Arnottianus A. Gray in Bot. U. S. Expl. Exped. 1: 176 (pro parte). 1854.
H. Arnottianus var. *Kokio* Hochr. Ann. Conserv. Jard. Bot. Geneve 4: 133. 1900.
H. Arnottianus forma Sinclair. Indig. Fl. Haw. Isl., p. 9. 1885.

DESCRIPTION: Tall shrub with straggly branches from the base, growing to 20 ft.; few lateral branches. Stipules 8 mm. long, glabrous. Petioles, 2–4 cm. long. Leaves 9–12 cm. long, 4–6 cm. wide, elliptical-ovate, long-acuminate apex, margin sinuately crenate, smooth surface, scarcely palmately veined. Peduncle 3.0 cm., articulate 5 mm. from involucre base. Involucre 6–7 lanceolate bracts, 1.3 cm. long, 1.5 mm. wide, slightly puberulent. Calyx 2.5–2.8 cm. long, 1.3 cm. wide, 10-veined, cleft 1 cm. from tips, 5 lobes, lanceolate, no glands, "lettuce green" in color, glabrate. Flowers axillary. Staminal column 5.5 cm. long, "scarlet red." Free filament tips extend 4 mm. from column, occupy apical 1.5 cm. of column. Style extension 4 mm.; style branches (horizontal) 8 mm. long. Petals 5.5 cm. long, 3.5 cm. wide, "scarlet red." Ovary truncate-conical, 6 mm. long, 4 mm. wide, pubescent (short, colorless hairs). Capsule glabrous, 2.5 cm. long. Seed reniform, 4 mm. long, brown, coarsely pubescent.

The nomenclature of this taxon is closely correlated with that of *H. Arnottianus* Gray. A discussion of their confusion can be found in the section of this paper dealing with the latter species. Gray's original description of *H. Arnottianus* included a fragment of a red-flowered hibiscus as well as the white.

TABLE 2

DISTINGUISHING CHARACTERS OF *H. Brackenridgei* POPULATION

CHARACTERS	*H. Brackenridgei*	VAR. *molokaiana*	VAR. *kauaiana*	VAR. *mokuleiana*
Growth habits	shrub	rambling shrub	rambling shrub	tree to 30 ft.
Leaf lobing	deeply cleft (5–7)	deeply cleft (5)	shallow-lobed (3)	moderately lobed
Leaf length	5 cm.	3–5 cm.	7–9 cm.	9–11 cm.
width	5 cm.	5–6 cm.	7–9 cm.	8–10 cm.
Stipules	0.5–1 cm. long	1 cm. long	1 cm. long	1–2 cm. long
Petiole	nearly glabrous	puberulent	densely pubescent	puberulent
Bract number	8–10	8–9	5	7–8
Bract shape	setaceous, terete	subulate, terete	hastate, not terete	subulate, terete
Bract glands	none	glands on inner side	none	none
Bract surface	almost glabrous	hirsute	hirsute	hirsute
Bract length	1 cm.	2.5 cm.	3.0 cm.	2–3 cm.
Calyx venation	10-veined	5-veined	5-veined	10-veined
Calyx length	1.5 cm.	1.5 cm.	2.5 cm.	3–4 cm.
width	1.5 cm.	1.0 cm.	1–1.5 cm.	1.5 cm.
Calyx glands	present	none	present	none
Petal length	3.5 cm.	5.0 cm.	6.0 cm.	8–10 cm.
width	2.5–3 cm.	4.5 cm.	5.0 cm.	5–8 cm.
Column length	4.0 cm.	4–5 cm.	2.5 cm.	7–8 cm.
	naked at base for 1 cm.	naked at base for 1 cm.	completely antheriferous	completely antheriferous

FIG. 8. *Hibiscus Brackenridgei* var. *mokuleiana* Roe. (Picture was presented by Joseph F. Rock.)

FIG. 9. *Hibiscus Kokio* Hbd. Plant collected on Nov. 23, 1956 at Kawaiiki Ditch Dam. Roe no. 204. (Thin straggly branch reaching 30 ft. in length.) Altitude 1,080 ft.

This red flower, as insignificant as it is in comparison with other luxuriant Hawaiian members of the genus, was designated in 1923 as the official flower of the Hawaiian Islands. This specimen has been collected by many botanists at the end of the Kawaiiki Ditch Trail overhanging the dam (Kawailoa, Koolau Range, elevation 1,080 ft.). From this location, many cuttings have been made and brought to cultivation.

As *H. Kokio* is known to hybridize freely, taxonomists hesitate to classify new groups. However, there seems to be a native red-flowered plant on eastern Kauai still undescribed. Sufficient material is not available to permit satisfactory classification; however, it appears that this group is a new species, closely allied to *H. Kokio* Gray and *H. kahilii* Forbes. The remaining Kauai native reds fall into either of the latter two taxa or that of the newly established species, *H. Saintjohnianus.*

At Puu Ka Pele in Waimea the Kokee rangers recently reported a red-flowered hibiscus. This has been collected by several botanists who have labelled it *Hibiscus* sp. After bringing it to cultivation and watching it for a year, the author has concluded that it is an introduced species bearing a large, reddish-purple flower.

HOLOTYPE: Fragment of the original type now in the Bishop Museum Herbarium reads "Ex Museo botanico Berolinensi." (From cultivated species in Hillebrand's garden.)

SPECIMENS EXAMINED: *Kauai:* In cultivation, 1913, Dewitt Alexander. Nonau Mountains, Oct. 16, 1916, *C. N. Forbes 599.K.* West side of Nualolu Pali, Waimea Drainage Basin, July 3, 1917, *C. N. Forbes 963.K.*

Oahu: Kanaikupai, Waianae Range, February 14, 1913, *C. N. Forbes 1814.O.* Kalihi Valley, October 1928, *A. F. Judd 37.* In cultivation at Queen Liliuokalani's Residence, Honolulu, Spring, 1916, *Rock.* Kawaiiki Ditch Trail, Kawailoa, Koolau Range, altitude 1080 feet, November 23, 1956, *Roe 204.* In cultivation at Foster Gardens, Honolulu, July 7, 1957, *Roe 226.* In cultivation at the Hibiscus Gardens at Waikiki, July 11, 1958, *Roe.* Ditch Trail (near intake), Koolau Range, 1922, *Skottsberg 203.* In cultivation, Honolulu, 1913, *Gerrit P. Wilder.*

FIG. 10. *Hibiscus Kokio* Hbd.

Hawaiian Islands: H. Mann and *W. T. Brigham, 218.*

7. *Hibiscus Kokio* var. *pukoonis* Caum
Fig. 11

Hibiscus Kokio var. *pukoonis* Caum. New Hawaiian Plants, Bishop Mus. Occ. Pap. 9(5): 7. 1930.

DESCRIPTION: A shrub 2–3 meters tall. Stipules 0.5–0.8 cm. long, setaceous. Petioles 2–4 cm. long. Leaves 8–12 cm. long, 4–7 cm. wide, ovate to elliptico-oblong, acuminate, sinuately crenate, scarcely palmately veined; soft-chartaceous. Peduncles 2.5–4.5 cm. long, solitary in axils near end of branches. Bracts 6–8, linear-lanceolate, 10–15 mm. long, 1.0–1.5 mm. wide, not adnate to clayx, glabrate. Calyx 2.5 cm. long, 1.0–1.3 cm. wide, cleft for 1.0 cm.; lobes acute, glabrate, tripli-nerved, the lateral nerves fuse 0.5–1.0 cm. below cleft, the calyx being 10-nerved at the base, nonglanduliferous. Petals 3–3.5 cm. wide, 6-nerved, slightly ciliate at margin, obovate, "scarlet red." Staminal column 5.0–6.0 cm. long, slender, light red, glabrous, acutely 5-lobed; free filament tips extend 0.3–0.4 cm.

from column, crowded on distal fifth of column. Style extension 2 mm. above column, branches 0.7 cm. long, red, ciliate, spreading slightly upward from the horizontal. Stigmas capitate, 0.1 cm. in diameter, red. Ovary truncate-conical, 0.5 cm. long, 0.3 cm. wide, scarcely puberulent with short appressed colorless hairs. Capsule glabrous, 1.5–2.0 cm. long. Seeds reniform, 0.4–0.5 cm. long, brown, coarsely pubescent.

In 1930, Caum published a variety of *H. Kokio* which he had collected just inside the native forest at the bottom of Pukoo Valley on Molokai (E. L. Caum, no. 155, Feb., 1921). He named this group of plants var. *pukoonis*. These plants do not flower freely and very rarely set fruit. They differ from the species in the texture and other characters of the leaf, petal shape and color, venation of the calyx, and other characters.

HOLOTYPE: E. L. Caum no. 155. Planted at Caum's Honolulu residence (1420 Piikoi St.), taken from bottom of Pukoo Valley, Molokai, just inside the native forest, February, 1921. (Specimen in the Herbarium of Bishop Museum.)

SPECIMENS EXAMINED: *Molokai:* Wailau Trail, 1912, *C. N. Forbes 327.Mo.* Halawa (the ridge south of the valley), August 1912, *C. N. Forbes 472.Mo.* Moist woods of Wailau Valley, elevation 500 feet, July 3, 1933, *St. John 13230.*

Oahu: In cultivation 1420 Piikoi St., Honolulu, October 8, 1930, *E. L. Caum 155* (duplicate). In cultivation in the University of Hawaii Arboretum, October 25, 1956, *Roe 202;* also April 14, 1957, *Roe 222.* In cultivation on Alexander Street, Honolulu, May 30, 1958, *Roe 270.* In cultivation, 2365 Oahu Avenue (brought from Molokai by W. T. Pope), 1931, *St. John 11170.*

8. ***Hibiscus Saintjohnianus*** sp. nov.
Figs. 12–14

DESCRIPTION: Arbor 6 m. alta basi 5–8 cm. in diametro. Stipulis 7–12 mm. longis. Petiolo 0.5–2.0 cm. longo piloso; lamina 6–12 cm. longa 3–5 cm. lata elliptica vel oblonga, margine basi versus integro, nervo medio conspicuo, nervis haud palmatis, viride spinacii colorata (cf. Ridgway). Pedunculo 1–1.5 cm. longo 3

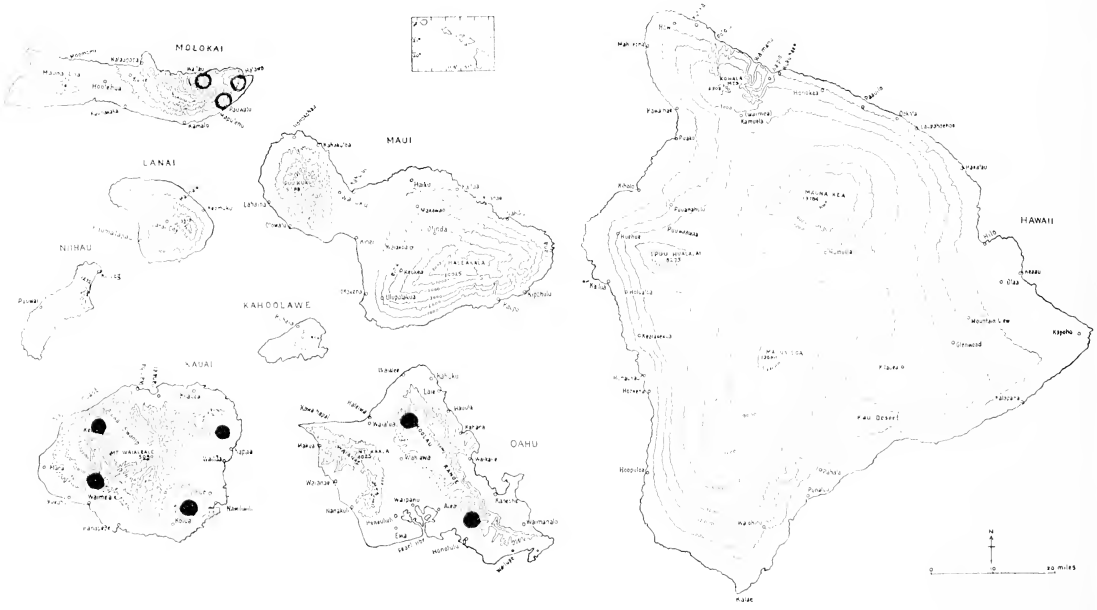

FIG. 11. Distribution of *Hibiscus Kokio* populations:
Solid circles, *Hibiscus Kokio*
Open circles, *Hibiscus Kokio* var. *pukoonis*

FIG. 12. *Hibiscus Saintjohnianus* Roe. Headland west of Hanakaiai, Napali Coast, Kauai. Altitude 700 ft. St. John 25989. Dec. 22, 1956.

mm. infra involucrum articulato; bracteis 7–8 lanceolatis 5–8 mm. longis. Calyce 3 cm. longo 1.5–1.8 cm. lato tubulato partito 1–1.3 cm. piloso 10-nervato lobis acutis viride lactucae coloratis (cf. Ridgway); petalis 6.5 cm. longis 2.5–3.0 latis rubro-coralaceis coloratis extus pubescentis; columna staminarum 6 cm. longa gracilis glabra in apice 5-lobata acuti, apicibus filamentium liberis 4–5 mm. longis in quarta superiore columnae collacatis. Ramuli styli 5, 1.0 cm. longi modice puberulenti in 1.5 mm. stigma globosa terminanti. Ovario 5-loculare 1.0 cm. longis 6–8 mm. latis. Capsula 2.0 cm. longa 2.5 cm. lata superne. Seminibus 4 mm. longis 3 mm. latis globoso-reniformibus, fusco-sericeis.

Tree 6 m. tall, diameter at base 5–8 cm. Stipules 7–12 mm. long. Petiole 0.5–2 cm., slightly pilose. Leaves 6–12 cm. long, 3–5 cm. wide, elliptic-oblong, upper three-fourths of margin serrate, lower fourth entire, midrib prominent, veins scarcely palmate, "spinach green." Peduncle 1–1.5 cm. long, articulate 3 mm. below the involucre. Lanceolate bracts 7–8, 5–8 mm. long. Calyx tubular, 3 cm. long, 1.5–1.8 cm. wide, cleft for 1–1.3 cm., lobes acute, pilose, 10-nerved, "lettuce green." Petals laterally subfalcate, 6.5 cm. long, 2.5–3.0 cm. wide, "coral red," puberulent on outer surface. Staminal column 6 cm. long, slender, glabrous, apex acutely 5-lobed. Free filament tips extend 4–5 mm. from column, located on the upper fourth of column. The 5-style branches slightly puberulent, 1 cm. long, each terminating in a 1.5 mm. discoid stigma. Ovary 5-parted, 1 cm. long, 6–8 mm. wide. Capsule 2.0 cm. long, 2.5 cm. wide at upper section. Seeds 4 mm. long, 3 mm. wide, globose-reniform, covered with a seriaceous pubescence, dark brown.

HOLOTYPE: Headland west of Hanakapiai, Napali Coast, Kauai. Altitude—700 feet; on partly precipitous slope. December 22, 1956. *H. St. John 25,989.*

SPECIMENS EXAMINED: *Kauai:* Hanakoa, altitude of 500 ft., Jan. 12, 1956, *H. F. Clay.* Kalalau Trail, Hanakapiai, September 1913, *C. N. Forbes 462.K.* Hanakapiai, between Hanakapiai Stream and Hoolulu Stream, 450 m. alt., December 24, 1956, *I. E. Lane 56-561.* In cultivation at Eleele, brought there from Awaawa Puhi Trail, Na Pali Kona Reserve, Waimea, July 29, 1957, *Roe 258.* In cultivation at Alexander Street, Honolulu; brought from Na Pali Cliff Trail, June 1, 1958, *Roe 271.*

FIG. 13. *Hibiscus Saintjohnianus* Roe. (Picture taken by Irwin Lane on the Napali Coast, Kauai.)

This species was brought to my attention by H. St. John, who has made several collections of it from Hanakapiai, Napali coast, Kauai. It has been confused with *H. Kokio* Hbd. and *H. kahilii* Forbes. To one who is familiar with these two native species, this plant is differentiated by the distinct leaf shape and by the vermilion-orange corolla. It has closest affinity to *H. Kokio,* from which it differs by its longer stipules, shorter bracts, larger calyx, longer yet narrower petals, longer staminal column, larger ovary, longer style branches, and shorter peduncle.

There are records at the Bishop Museum stating that J. M. Lydgate brought it to cultiva-

tion at his home on Kauai. I investigated the grounds of his estate in 1957, desiring to locate this and other native *Hibiscus* that have been recorded as planted there by him, but none of them remain.

This species is in cultivation on Kauai, as I recognized it on several occasions, collecting it in Eleele. The Eleele plants were recorded as having been brought from Awaawa Puhi Trail, Na Pali Kona Reserve (Waimea).

Irwin Lane, University of Hawaii, located the species in 1957 at Hanakapiai.

I have the plant in cultivation on Alexander Street, Honolulu. It is also growing at Foster Botanical Gardens in Honolulu. Both plants are from cuttings made by St. John on the Napali coast, Kauai.

9. *Hibiscus kahilii* C. N. Forbes
Fig. 14

Hibiscus kahilii C. N. Forbes. New Hawaiian Plants, Bishop Mus. Occ. Pap. 5(1): 4. 1912.

DESCRIPTION: Tree growing to 8 m. Petiole 3–8 mm. long, scabrous on both sides of blade and petiole. Leaves 5–7 cm. long, 3–5 cm. wide, ovate-elliptic, margin serrate on the upper half, lower portion entire. Peduncles 1.5 cm. long, flowers axillary. Calyx 2.5–3.0 cm. long, 1–1.5 cm. width at throat, cleft 2–3 mm. from top, pubescent. Petals 6.0–6.5 cm. long, 1.0 cm. wide, bright red, pubescent on outer side only, oblong-spatulate. Staminal column 5 cm. long. Styles 8–10 mm. long. Capsule unknown.

HOLOTYPE: Near Wahiawa Swamp, foot of Mt. Kahili, Wahiawa Mountains, Aug., 1909. *C. N. Forbes 259.K.*

SPECIMENS EXAMINED: *Kauai:* Wahiawa Mountains, *Lydgate.* May 1909, *Rock 40 (2701).* Northwest facing slope, ridge ¾ mile north of Laakahi, Koloa, 900 ft. altitude, moist gulch, December 24, 1947, *St. John 23023.*

Oahu: In cultivation on Palolo Street, brought there from Kauai, Oct. 25, 1956, *Roe 201.*

This species was described by Charles N. Forbes in 1911. It is closely related to *H. Kokio* Hillebrand, from which it differs by its pubescent calyx, smaller leaf, shorter petioles, shorter peduncle, longer yet narrower petals, shallower cleft, and longer style extension.

This species is poorly known. Forbes claimed it was first collected by Lydgate several years before he made his type collection in August, 1909. Rock (1913*a*) cited Forbes' species but did not give it lengthy treatment. Rock recently tried to find *H. kahilii* again on Kauai but was unsuccessful. In a letter dated August 15, 1958, from Albert Duvel, Kauai forester, we find *H. kahilii* still difficult to obtain. Duvel wrote, "I am not able to locate a place or specimen of *H. kahilii.*" The last record of it in its native environment was in 1947, when St. John (no. 23,023) collected the species on a ridge .75 mi. north of Laaukahi, Koloa, Kauai. It was in a moist gulch at 900 ft. altitude. This species has been found in cultivation in Honolulu.

In the herbarium at the Bishop Museum there are several specimens of a plant closely allied to *Hibiscus kahilii.* These were collected by Forbes (643.K) on October 22, 1916, in the Hii Mountains, Kauai. This population is undoubtedly a variety of *H. kahilii,* as it resembles it in most characters. The stem surface of these specimens is distinct, and the leaves are larger and by far more pubescent. I am unable to completely describe this variety at present, as sufficient material is not at hand. It has not been reported since 1916.

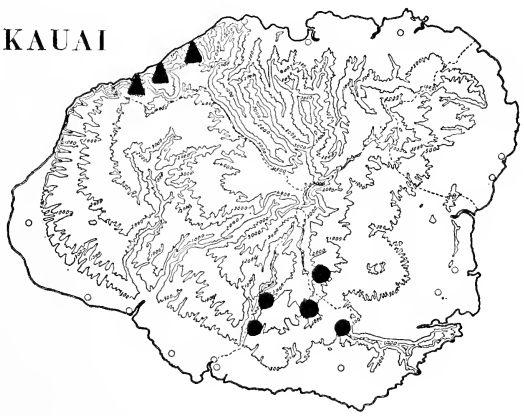

FIG. 14. Distribution of *H. kahilii* and *H. Saintjohnianus:*
Solid circles, *H. kahilii*
Solid triangles, *H. Saintjohnianus*

10. ***Hibiscus Newhousei*** sp. nov.
Fig. 15

DESCRIPTION: Arbor 6 meters alta. Stipulis 4–6 mm. longis. Petiolo 0.3–1.8 cm. longo piloso. Lamina 4.5–9.0 cm. longa 2.5–4.0 cm. lata. Pedunculo 0.7–0.9 cm. longo articulato 2 mm. infra involucrum; bracteis lanceolatis 7–8 mm. longis. Calyce 1.8–2.0 cm. longo 1.0–1.4 cm. lato, furcato 0.3–0.7 cm. cum lobis acutis, 10-nervoso piloso. Petalis 5.0–5.2 cm. longis 1.3–1.6 cm. latis, rubro colorato. Columna staminarum 3.0–3.8 cm. apicibus filamentium liberis ca. 4 mm.

Tree 6 m. tall. Stipules 4.0–6.0 mm. long. Petiole 0.3–1.8 cm. long, pilose. Leaves 4.5–9.0 cm. long, 2.5–4.0 cm. wide; margin irregular, apex distinctly acuminate. Peduncle 0.7–0.9 cm. long, articulate 2 mm. below the involucre. Lanceolate bracts 6–8, 7–8 mm. long. Calyx tubular 1.8–2.0 cm. long, 1.0–1.4 cm. wide, cleft for .3–.7 cm., lobes acute, pilose, 10-nerved. Petals 5.0–5.2 cm. long, 1.3–1.6 cm. wide, dark red, puberulent on outer surface. Staminal column 3.0–3.8 cm. long, slender, glabrous, apex 5-lobed. Free filament tips extend ca. 4 mm. from column, located on the upper half of the column.

HOLOTYPE: Moloaa Forest Reserve, Kauai; ca. 500 feet altitude. November 10, 1958. *I. E. Lane 44.*

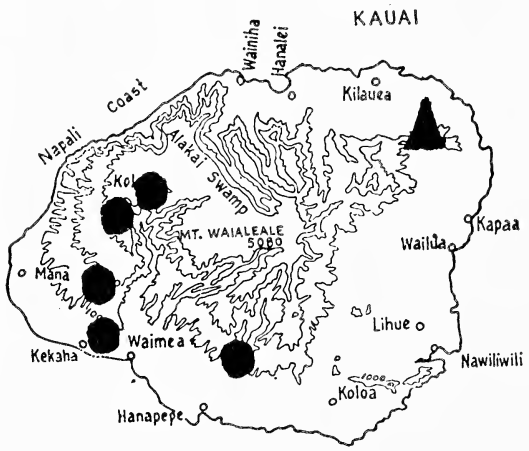

FIG. 15. Solid circles, *Hibiscus waimeae;* solid triangles, *Hibiscus Newhousei.*

This group is the most recent of the indigenous hibiscus to be discovered. It had been reported several years ago and rediscovered in 1957. Mr. and Mrs. Jan Newhouse found it growing along the Moloaa Stream in the Moloaa Forest Reserve, northeastern section of Kauai. They brought it to cultivation at that time. A year later Irwin Lane made a second collection in its original habitat. Lane sent cuttings to the Foster Gardens in Honolulu, where this species can now be found.

One of its notable characters is its distinctly acuminate leaves. *H. Newhousei* shows closest proximity to the native *H. Kokio,* from which it differs by leaf shape and size, shorter peduncles, shorter bracts, smaller calyx, shallower clefts, shorter column, and other characters. Flowers are dark red and leaves are deep green on both surfaces.

11. ***Hibiscus immaculatus*** sp. nov.
Figs. 16–18

DESCRIPTION: Arbor 3 meters alta basi 6 cm. in diametro. Petiolo 1.0–1.5. Lamina 5–7 cm. longa 4–6.5 cm. lata ovati-obovata margine dentate, nervis haud palmatis viride lactucae nervo medio subter pubescente stellato. Pedunculo 2–3 cm. longo 2–3 mm. lato articulato 1 cm. infra involucrum; bracteis lanceolatis 5–8 mm. longis. Calyce 2.5–3.0 cm. longo, 0.8–1.0 cm. lato, furcato 4 mm., cum lobis acutis, 10-nervoso piloso flavi-virente. Petalis 8–11 cm. longis 2.5–3.5 cm. latis glabris albis. Columna staminarum 10–14 cm. paulo papillosa apicibus filamentium liberis 10–20 mm. longis. Ramuli stylorum 1.5–2.0 mm. longi erecti papillosi. Ovario 1.0 cm. longo 7–8 mm. lato.

Tree 3 m. tall, diameter at base 6 cm. Petiole 1.0–1.5 cm. Leaves 5–7 cm. long, 4–6.5 cm. wide, ovate-obovate, margin denticulate, veins scarcely palmate, "lettuce green," midrib bears slight stellate puberulence on underside. Peduncle 2–3 cm. long, 2–3 mm. wide, articulate 1 cm. below involucre. Lanceolate bracts 6, 5–8 mm. long. Calyx 2.5–3.0 cm. long, 0.8–1.0 cm. wide, cleft for 4 mm., lobes acute, 10-nerved, pilose, "dull green yellow." Petals 8–11 cm. long, 2.5–3.5 cm. wide, glabrous, white. Staminal column 10–14 cm. slightly papillate. Free filament

FIG. 16. *Hibiscus immaculatus* Roe. Pali of Olokui above Waiehu, Wailau Valley, Molokai. Sept. 1912. C. N. Forbes 551.Mo.

FIG. 17. *Hibiscus immaculatus* Roe.

tips 10–20 mm., located on the upper third of column. Style branches 1.5–2.0 mm., erect, papillate. Ovary 1.0 cm. long, 7–8 mm. wide.

HOLOTYPE: Pali of Olokui above Waiehu, Wailau Valley, Molokai, September 1912. *C. N. Forbes 551.Mo.*

SPECIMENS EXAMINED: Wailau Valley, Molokai, *C. N. Forbes 550.Mo.* Hibiscus Gardens in Honolulu, introduced from Molokai, July 10, 1958. *Roe 301.*

In September, 1912, Forbes made several collections of a distinct white hibiscus from the Pali of Olokui above Waiehu, Wailau Valley, Molokai. He noted that the staminal column was entirely white, which is not the case in our other Hawaiian white-corolled species. Forbes at first considered this a form of *H. Arnottianus;* in fact an early label read: "*H. Arnottianus* Gray Form nov." Forbes, following subsequent study of his specimens of the plant, concluded it was a distinct species and noted this on his herbarium sheets. However, he did not leave any description of the new species. In 1913 Rock related that this "pure white flowered one occurs on the beach of Wailau Valley on Molokai." A letter written on July 16, 1958, by Henry Wiebke, Hoolehua, Molokai, confirmed the fact that the species continues to exist in the original locality. Mr. Wiebke wrote: "There is a native white hibiscus still growing in Wailau Valley in and around Kalae. Records show that these have been reported a number of times. This one is completely white."

The plant has also been found in cultivation in Honolulu, and in each case its origin has been traced to Molokai. It is attractive, but smaller and less showy than *H. Arnottianus.* Its rounded leaf of "lettuce green" is quite distinctive and this, together with the pure white corolla and column of the flower, makes it a desirable plant for cultivation.

12. *Hibiscus waimeae* Heller
Figs. 15, 19, 20

Hibiscus waimeae Heller. Observation of the Ferns and Flowering Plants of the Hawaiian Islands, Minn. Pub. of Botany (1897) 851, pl. 53.

H. Arnottianus Gray forma. Mrs. Sinclair, Indigenous Flowers of Hawaiian Islands (1885), pl. 8.

H. waimeae var. *Helleri.* Hochreutiner, Ann. Conserv. Jard. Bot. Geneve 4: 132, 1900.

DESCRIPTION: Tree 7–8 m. in height; DBH, 16 cm. Stipules 5–6 cm. long, lanceolate. Petioles 3–4 cm. long, 2–3 mm. wide, puberulent. Blade 6–9 cm. long, 5–7 cm. wide, obovate-orbicular, surfaces entirely velvety pubescent, margin serrate, "forest green." Peduncles 2–3 cm. long, articulate 6 mm. below involucre. Bracts 7, lanceolate, 1.5–2.5 cm. long, pubescent. Calyx 3.5–4.0 cm. long, 1.0–1.5 cm. wide, widest at base of teeth, cleft 1–1.5 cm. from apex, teeth ovate-lanceolate, velutinous. Corolla white, pubescent on outer surface. Petals ca. 14 cm. long, 4–5 cm. wide (at greatest width), prominently veined. Staminal column stout, long exerted,

FIG. 18. Distribution of *Hibiscus immaculatus:* Solid circles, represent localities of collections Open circles, represent areas where plants have been reported

FIG. 19. *Hibiscus Waimeae* Heller. Kokee region of the Na Pali Kona Reserve, altitude 3,200 ft., on bank of canyon. Jul. 29, 1957. Roe 261.

red. Filament tips extend approximately 2 cm. from column.

HOLOTYPE: Kaholuamanoa above Waimea, 900 m. September 2–9, 1895. *A. A. Heller 2785.* (Isotype examined.)

SPECIMENS EXAMINED: *Kauai:* Waimea Canyon, January 12, 1956, H. F. Clay. Mountains back of Waimea, September 1909, *C. N. Forbes 422.K.* Waimea Drainage Basin, West side (humid forest), July 3–August 18, 1917, *C. N. Forbes 993.K.* Halemanu February 20, 1909, *Rock 39 (1559).* Below Kaholuamano in gulches at 1800 feet, September 1909, *Rock 5629.* October 1916, *Rock 17093.* Kokee region of Na Pali Kona Reserve, altitude of 3200 feet on bank of canyon, July 29, 1957, *Roe 261.* In cultivation at Kalaheo, altitude of 750 feet, July 27, 1957, *Roe 252.* In cultivation at the Hibiscus Gardens of Honolulu, July 2, 1958, *Roe 290.*

This species, although closely related to *H. Arnottianus* and unfortunately confused with it, is very different in numerous distinct characters, such as petals, column, stamens, calyx, leaves, tree shape, pubescence, and texture. Hillebrand considered all Hawaiian white-flowered hibiscus to be *H. Arnottianus.* Heller studied the situation and felt that the white-flowered plant from Kauai was distinct and unnamed. He published its description in 1897. In 1900, Hochreutiner reopened the case of *H. Arnottianus.* (A thorough discussion of this situation will be found in my treatment of *H. Arnottianus.*) To the large Oahu white, Hochreutiner attached the name of *H. waimeae* (Heller) var. *Hookeri* Hochr., and to the real *H. waimeae* of Heller he gave the name *H. waimeae* var. *Helleri* Hochr. Hochreutiner gave the name *H. Arnottianus* to what is known today as *H. Kokio* Hbd., thus establishing two varieties. T. A. Sprague in 1914 also added to the confusion. He suggested the name *H. Arnottianus* be dropped completely and replaced by *H. waimeae.* Skottsberg in 1926 concluded that the treatment given by Hochreutiner and Sprague is "... inadmissible and has resulted in a more and more hopeless confusion...." He continued, "...to replace 'Arnottianus' with 'Waimeae' Heller, to distinguish two varieties of this and to call Heller's type var. Helleri is wrong for the simple reason that 'Arnottianus' Hillebrand and 'waimeae' are different species."

FIG. 20. *Hibiscus waimeae* Heller.

The major differences between *H. Arnottianus* and *H. waimeae* are these: *H. Arnottianus* is nearly glabrous throughout, while *H. waimeae* has a velvety pubescence. The petioles of the Kauai species are almost twice as long as those of the Oahu plant; their calyces are also longer and wider. The calyx cleft of *H. Arnottianus* is only 5 mm. deep and that of *H. waimeae* is 1–1.5 cm. deep. The staminal column of *H. waimeae* is stouter than that of the Oahu species.

13. *Hibiscus Arnottianus* Gray
Figs. 21–23

Hibiscus Arnottianus Gray. Bot. U. S. Expl. Exped. 1: 176. 1854.

H. Boryanus H. & A. Bot. Beechey Voy., p. 79, partim, non DC. 1832.

H. Waimeae var. *Hookeri* Hochreutiner. Ann. Conserv. Jard. Bot. Geneve, 4: 132. 1900.

H. Fauriei Leveil. Fedde Repert. 10: 120. 1911.

DESCRIPTION: Tree growing to 35 ft., well branched, nearly glabrous. Stipules subulate, caducous. Petioles 0.5–2.0 cm. long, glabrous. Blades 8–10 cm. long, 5–7 cm. wide, ovate to elliptical-parabolical, apex acute-acuminate, chartaceous, margin sinuately crenate to entire,

FIG. 21. *Hibiscus Arnottianus* Gray. North end at junction of Manoa Cliff and Pauoa trails; 1,300 ft., Tantalus, Manoa. (Tree 8 m. × 2 dm.), Apr. 17, 1957. St. John 26053.

scarcely palmately veined with 3 strong nerves and 2 less prominent nerves branching from base of blade. Flowers solitary in axils of leaves. Involucre with 5–7 linear-lanceolate bracts 0.7–1.0 cm. long. Calyx tubular, 2–3 cm. long, 0.8–1.0 cm. wide, 5 acute lobes, cleft 5 mm. from apex, glabrous to slightly pilose. Corolla white often with a slight pink tinge. Petals 7–12 cm. long, 2–3 cm. wide. Staminal column long exerted, 10–15 cm. long, red, free filament tips 1.0–1.8 cm. long, from upper half of column. Style branches erect, 5–8 mm. long. Capsule chartaceous, 2–3 cm. long. Seeds reniform, 4–5 mm. tomentose, dark brown.

SPECIMENS EXAMINED: *Oahu:* North slope of Mt. Tantalus (tree 6 m. tall; 45 cm. DBH), June 15, 1930, *Christopherson 1373.* Beside stream in open forest, Wailupe, Kului, June 23, 1937, *F. E. Egler No. 37–68.* Konahuanui, Jan. 6, 1909, *C. N. Forbes 1000.O.* East side of Nuuanu Valley, Oct. 1910, *C. N. Forbes 1601.O.* Waialae Valley, October 15, 1914, *C. N. Forbes 1948.O;* also May 4, 1914, *Forbes 2496.O;* and January 1919, *Forbes 2522.O.* Manoa Cliff Trail, April 11, 1920, *Gerber D. Wesley 372.* "Hauhele" *Hillebrand.* Niu, *Hillebrand* and *Lydgate.* Tantalus Ridge, September 5, 1909, *H. L. Lyon.* "Oahu" *H. Mann* and *W. T. Brigham 530* (2 sheets). Mt. Tantalus, July 8, 1922, *C. Skottsberg 84.* North end at junction of Manoa Cliff and Pauoa Trails, 1300 feet, Tantalus, Manoa (tree 8 m. x 2 dm.), April 17, 1957, *St. John 26053.*

There has been so much confusion and controversy regarding Gray's *H. Arnottianus* that a presentation of its history is necessary. His original description (1838) of *H. Arnottianus* reads:

H. fructicosus, glaberrimus; foliis ovatis sen ovalibus subcoriaceis integerrimis (nunc subdentates) basi tri-nervatis; floribus solitariis pedunculatis; involucelli phyllis 5–7 parvis deciduis; petalis (rubis) oblongis basi attenuatis atque in tubum gracilem calyce cylindrico longiorem coalitis; columna staminea proelonga spithamoea; capsula polysperma.

Hibiscus Arnottianus, Gray in herb. Hook anno 1837

H. Boryanus, Hook & Arn Bot. Beech. Voy. non DC

Hab. Sandwich Islands; on the Kaala Mountains behind Honolulu, Oahu; where it was gathered by Macrae, Lay & Collie, Diell, Barclay, etc. (Byron's Bay, Hawaii; Macrae, Diell.)

This description includes a red-flowered hibiscus having the long staminal column characteristic of the white-flowered Oahu plant. There are at least two distinct species included in Gray's description of *H. Arnottianus.*

Hillebrand described as new the small red-flowered hibiscus, calling it *H. Kokio* Hbd. He stated his belief that the red-flowered hibiscus from Byron's Bay, referred to by Hooker and Arnott under *H. Boryanus* and considered by Gray as the *H. Arnottianus* from "Byron's Bay, Hawaii, Macrae," belonged to the taxon *H. Kokio.*

Hillebrand applied the name *H. Arnottianus* to the plant collected during Beechey's voyage and distinguished it from his newly described *H. Kokio.* It is presumed that Hillebrand studied the types.

Heller in 1897 studied both plants in question and concluded that Gray's type for *H. Arnottianus* was probably collected by Diell at Byron's Bay and that it had red flowers. Heller at that time was in a position to designate the type but did not do so. Gray mentioned first "the Kaala mountains behind Honolulu" and secondly, in brackets, "Byron's Bay, Hawaii, Macrae, Diell." Heller felt that the white-

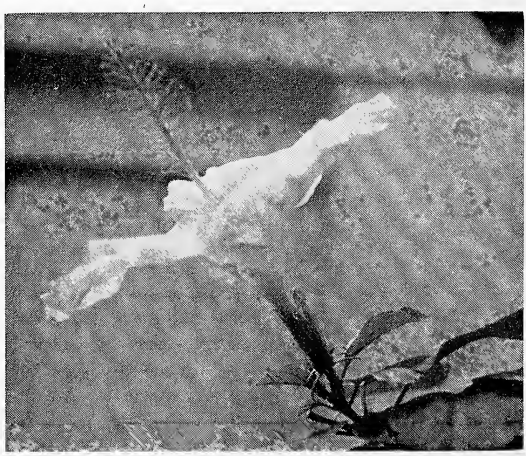

FIG. 22. *Hibiscus Arnottianus* Gray.

flowered Kauai hibiscus was distinct from both *H. Arnottianus* and *H. Kokio,* and he described it as *H. waimeae.*

In 1900 Hochreutiner published his revision of the genus *Hibiscus,* including the Hawaiian species. He presented a new interpretation of *H. Arnottianus.* While Hillebrand and Heller had applied Gray's description to the plant collected during Beechey's voyage, Hochreutiner felt that the name *H. Arnottianus* belonged to the plant collected by Diell, called by Hillebrand *H. Kokio.*

Hochreutiner classified the plants in question as follows:

H. Waimeae Heller	(white-flowered species)
var. *Hookeri* Hochr.	(Beechey plant)
var. *Helleri* Hochr.	(Kauai white)
H. Arnottianus Gray	(red-flowered species)
var. *Kokio* Hochr.	(Hillebrand's *H. Kokio*)
var. *genuinus* Hochr.	(Byron's Bay- red- Macrae, Diell)

Rock (1913*a*) makes no mention of Hochreutiner's revision, which leads one to believe that he was not familiar with it. He was aware, however, of the original problem regarding *H. Arnottianus* and, to verify his classification, he sent a specimen of the white-flowered *H. Arnottianus* to the Gray Herbarium, where B. L. Robinson made comparisons and replied, "There can be no question that the white-flowered species (No. 8831) from Oahu is precisely the real *H. Arnottianus* Gray." As far as Rock was concerned the case of *H. Arnottianus* was settled. However, in 1914, T. A. Sprague began again to dispute its nomenclature. He wrote in the Kew Bulletin, "So much confusion has arisen in the past in connection with the name *H. Arnottianus* that it is perhaps desirable to abandon the use of it altogether." Sprague claimed that Gray had a red-flowered species in mind when describing *H. Arnottianus,* for he sent a specimen of this species collected by Diell to Sir William Hooker under the name *H. Arnottii* Gray (later altered to *Arnottianus*). However, Sprague disregarded the name *H. Arnottianus* entirely and retained *H. Kokio* Hbd. for the red-flowered species.

Skottsberg (1926), in reviewing the nomenclatural history of *H. Arnottianus,* exclaimed, "The confusion is very complete." His conclusion, however, is very sound and offers the only logical solution to the problem. He rebuked Hochreutiner and Sprague for their "inadmissible" treatment given to the species in question, and joined Rock in his view of the situation.

It is concluded that Gray had two species on hand when he described *H. Arnottianus*—the white-flowered Oahu hibiscus bearing the long staminal column, and the small red-flowered plant. The red plant was the material sent to Sir William Hooker and the white-flowered species was retained in the Gray and the U. S. National Museum herbaria. This white species compares to our Oahu white according to the judgment of Dr. Robinson. In a recent letter, Reed C. Rollins, director of the Gray Herbarium, also testified that *H. Arnottianus* from the Wilkes Expedition is "white-flowered, with a very long, apparently red, staminal column."

Likewise, Richard S. Cowan of the U. S. National Museum, in a letter dated June 28, 1958, confirmed this belief regarding the material deposited there. Cowan wrote:

We have one sheet bearing one flowering branch collected by the U. S. Exploring Expedition; the label is the standard label for this Expedition but the locality is in long-hand and reads: "Oahu, S. Islands." The only other notation is the name "Hibiscus Arnottianus Gray." I have compared both the quoted items with a scrawl of Gray's in our holograph collection and I feel certain that they were made by the same person. There is no question in my mind that the specimen is of the white-flowered element, for red-flowered *H. Kokio* clearly shows red flowers even in the dried condition. The length of the staminal column in one of the two flowers on our specimen is 10.5 cm. In most respects, this specimen appears very similar to the following collections in our herbarium assigned to *H. Arnottianus:* Mann & Brigham 530 and Christopherson 1373.

Skottsberg agreed that Hillebrand could retain either of the two species as *H. Arnottianus* and then describe the other as new (for Gray did not designate a type). Hillebrand considered the white-flowered Oahu plant as *H. Arnottianus* and described the red as *H. Kokio.* According to the international rules of nomenclature, the solution worked out by Hillebrand must be accepted and is correct. We have the testimony of Rock and Skottsberg to this. The full synonomy given by Skottsberg is correct:

H. Arnottianus (A. Gray p.p.) Hbd. s. str. (excluding Kauai specimens *H. waimeae*); Rock, non Hochreutiner.

Syn: *H. waimeae* (Heller) var. *hookeri* Hochr.; T.A.S.; *H. fauriei* Levl.

H. waimeae Heller; Rock.

Syn: *H. Arnottianus* Hbd. quoad spec. kauaiens

H. Arnottianus forma, Mrs. Sinclair, pl. 8.

H. waimeae (Heller) var. *helleri* Hochr.

H. Kokio Hbd; Rock, T.A.S.

Syn: *H. Arnottianus* Gray; Hochreutiner; non Hbd., Rock.

H. Arnottianus forma, Mrs. Sinclair, pl. 9.

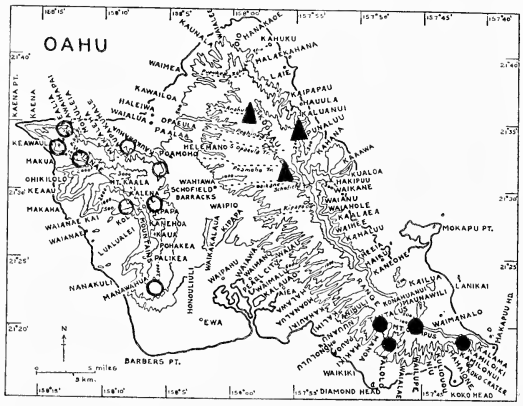

FIG. 23. Distribution of *H. Arnottianus* populations:
Solid circles, *H. Arnottianus*
Open circles, f. *parviflora*
Solid triangles, var. *punaluuensis*

H. Kokio Hbd; Rock, T.A.S.

Syn: *H. Arnottianus* Gray pro parti; Hochreutiner; non Hbd., Rock.

H. Arnottianus forma, Mrs. Sinclair, pl. 9.

We conclude from this discussion that we have three distinct species: the two whites, *H. Arnottianus* and *H. waimeae;* and one red, *H. Kokio.* Hillebrand effectively restricted application of *H. Arnottianus* to a white by naming the red.

14. *Hibiscus Arnottianus* f. *parviflora* Skottsberg
Fig. 23

Hibiscus Arnottianus f. *parviflora* Skottsberg. Vascular Plants from the Hawaiian Islands, IV. Acta Hort. Gotoburg. 15: 396. 1944.

DESCRIPTION: Tree to 30 ft.; well branched. Stipules subulate, caducous. Petioles 0.5–1.5 cm. long. Leaves 4–6 cm. long, 4–5 cm. wide; crenulate to entire, glabrous to slightly stellate-pilose on the underside of leaf. Bracts 5–7, linear-lanceolate, 5–8 mm. long. Calyx tubular, 1–2 cm. long, 0.5–1.1 cm. wide, slightly pilose. Petals 6–6.5 cm. long; 2.5–3.0 cm. wide. Staminal column long exerted, 8–12 cm. long, red, free filament tips extend 1.0–1.5 cm. from column, style branches erect, 5–8 mm. long.

HOLOTYPE: One mile south of Kolekole Pass, Waianae Mountains. (Hawaiian Bog Survey) September 3, 1938, *O. Selling 3364.*

SPECIMENS EXAMINED: *Oahu:* Palehua, Waianae Range, *C. M. Cooke.* Kupehau Gulch, elevation 1800 feet, Waianae Range, October 13, 1946, *Cowan 165.* Kukuiula, Mokuleia, Waianae Range (Forest Trail N. 20a) elevation 1200 feet, tree 30 feet, *William H. Hathaway 163.* Puu Hapapa, Waianae Mountains, elevation 2400 feet, October 19, 1930, *E. Y. Hosaka 325.* Ekahanui Gulch, Waianae Mountains, elevation 1200 feet, September 28, 1947, *Yoshio Kondo.* Keekee Gulch, in unfenced forest reserve, elevation 1500 feet, October 13, 1941, *Korte.* Makaha Valley, Waianae Mountains, January 31, 1927, *MacDaniels 569.* Waikane Mauka Trail on the Waianaeuka-Wahiawa Divide, elevation 1250 feet, March 15, 1958, *Roe 266.* Kealia,

elevation 1500 feet, edge of woods; tree 8 m. × 25 cm., November 8, 1936, *St. John 17,655.* Mokuleia Trail, Waianae Range, elevation 2200 feet, tree 6 m., January 11, 1948, *Webster L. Grady 1180.*

This population was brought to our attention in 1944 when Skottsberg published it as a form of *H. Arnottianus* Gray. Skottsberg felt that the variation was slight and showed principally in the smaller flower. Besides the flower difference, the leaves, calyx, and bracts of this form appear smaller than those of the species.

15. *Hibiscus Arnottianus* Gray var. *punaluuensis* Skottsberg
Fig. 23

Hibiscus Arnottianus Gray var. *punaluuensis* Skottsberg. Vascular Plants from the Hawaiian Islands, IV. Acta Hort. Gotoburg. 15: 396. 1944.

H. punaluuensis (Skottsb.) Deg. & Deg. Flora Hawaiiensis 5: Family 221. 1957.

DESCRIPTION: Tree to 35 ft. Stipules subulate, caducous. Petioles densely puberulent, 3–12 cm. long, scarcely palmately veined (5 radiating ribs), veins strongly pubescent. Blade 10–25 cm. long, 8–20 cm. wide with puberulent-pilose surface, ovate, base subcordate, apex acuminate. Bracts 5–7, linear-lanceolate, 1.0–2.0 cm. long, pilose. Calyx scabrous, 1.8–2.5 cm. long, 1.0–1.5 cm. wide, cleft 5 mm. Petals white, 8–12 cm. long, 2.5–4 cm. wide, stellate pubescent on outer surface. Staminal column red, 12–19 cm. long, free filament tips 1.5–2.5 cm. long, red. Style branches 1.0 cm. long.

HOLOTYPE: Punaluu, Koolau Mountains, Oahu (Hawaiian Bog Survey) Sept. 27, 1938. *O. Selling 3638.* (Isotype examined; type not seen.)

SPECIMENS EXAMINED: *Oahu:* Edge of Kaluanui Stream, Castle Trail, December 22, 1940, *E. H. Bryan, Jr. 1501.* Between Punaluu and Kaipapau, Koolau Mountains, November 14–21, 1908, *C. N. Forbes.* Near Head Gate, Wahiawa, August 17–20, 1915, *C. N. Forbes 2198.0.* Punaluu, elevation 2000 feet, September 28, 1930, *E. Y. Hosaka 304.* Kaluanui River Bank, Koolau Mountains, elevation 2800 feet, September 28, 1930, *Inafuku.* Upper Kaluanui Valley, Castle Trail, October 21, 1945, *R. Kuykendall 117.* Waiahole Ditch Trail, June 1932, *A. Meebold.* Near Mt. Stream, Koolau Mts., Nov. 14–21, 1908, *Rock 37 (309)* (duplicate). In cultivation in Wilder's Garden, *J. F. Rock.* Along Puunahia streams near Castle Camp, tree 30 feet, August 1911, *Rock 8831.* Kaluani, Castle Trail, Koolau Range, November 14, 1955, *Roe 18.* Kaluanui, by stream 1950 feet altitude, rain forest, tree 7 m. × 15 cm., November 25, 1956, *St. John 25977.*

Skottsberg in 1944 established this new variety, *punaluuensis,* and called it after the locality where the type was collected. It differs from the species by a characteristic venation: between the base with the five radiating ribs and the next strong pair (which forms an angle of 45 degrees with the midrib) is a wide stretch with only faint veins issuing at an angle of about 90 degrees. The leaves are longer and wider than those of the species, the petiole being approximately 5 cm. longer. The veins are strongly pubescent. The free filament tips and style branches are longer in the variety. The calyx is conspicuously hairy.

In 1957 Otto Degener raised this population to the status of a species. These plants differ from *H. Arnottianus* but show such similarity that I hesitate to agree with Degener. The differences are not so great as they are between the other taxa which have been accorded specific rank. Skottsberg's treatment seems more satisfactory.

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A Collection of Porifera from Northern New Zealand, with Descriptions of Seventeen New Species

PATRICIA R. BERGQUIST[1]

THE MATERIAL DESCRIBED HEREIN has been collected by the author during the course of investigations into the intertidal and sublittoral ecology of the sponges of Northland.

Burton (1932), in reporting the "Discovery" Antarctic sponges, remarked on the relatively advanced state of knowledge of that fauna and added only 35 new species from this collection. In strong contrast stands the lack of knowledge of the littoral sponge faunas of New Zealand, particularly of the siliceous groups. The present collection contains 34 species, all relatively common members of the northern shore faunas. Of this number, 17 are new species, and 11 are recorded for the first time from New Zealand.

No Calcarea are included in the present study. They are, in general, better known than the Demospongiae, as most of the published work by Kirk dealt with this group.

All type material is to be deposited in the Dominion Museum, Wellington.

SYSTEMATIC DISCUSSION

The scheme of classification followed is that of de Laubenfels (1936).

CLASS DEMOSPONGIAE (Sollas)

ORDER KERATOSA (Grant)

FAMILY SPONGIIDAE (Gray)

GENUS *Ircinia* (Nardo)

Ircinia novae zealandiae, sp. nov.
Fig. 1*a*

OCCURRENCE: Noises Islands, Hauraki Gulf. 12/10/56.[2]

DESCRIPTION: The sponge is irregularly palmo-digitate in shape, the surface irregularly conulose. Oscules are small, 1–2 mm. in diameter, few in number, and indiscriminately scattered. The texture when dried is hard and the colour blackish-brown. The texture when fresh is elastic and the colour blackish.

The skeleton is a reticulation of strongly fasciculated fibres showing obvious differentiation into ascending and connective fibres. These fibres vary from .02 to 1.0 mm. in diameter. Foreign inclusions are occasionally present, sometimes filling the whole of a fibre. Filaments are not common and are .004 mm. in diameter.

GENUS *Spongia* (Linnaeus)

Spongia reticulata (Lendenfeld)

Euspongia reticulata (Lendenfeld, 1886, p. 541).

Hippospongia reticulata (Lendenfeld, 1889, p. 300, pl. 13, fig. 3).

OCCURRENCE: Rangitoto sublittoral fringe.
DISTRIBUTION: Australia.

FAMILY DYSIDEIDAE (Gray)

GENUS *Dysidea* (Johnston)

Dysidea cristagalli, sp. nov.
Fig. 1*b*

OCCURRENCE: Noises Islands, 2/5/37 (coll. L. B. Moore). Rangitoto, 7/6/57. In rock pools in caves.

DESCRIPTION: The sponge is erect, tubular in shape, with several tubes coalescing to give a tubula-flabellate condition. The surface is uneven and the oscules apical, giving access to deep cloacae. The texture is firm and friable, the colour ash-grey. The skeleton is an irregular, closely knit reticulation of fibres varying in diameter from .02 to .2 mm. and having no obvious distinction between ascending and connective fibres. The fibres are filled with broken sponge spicules. There is no special dermal skeleton differentiated.

[1] Department of Zoology, University of Auckland, New Zealand. Manuscript received August 7, 1959.

[2] In this paper, dates are given as day/month/year.

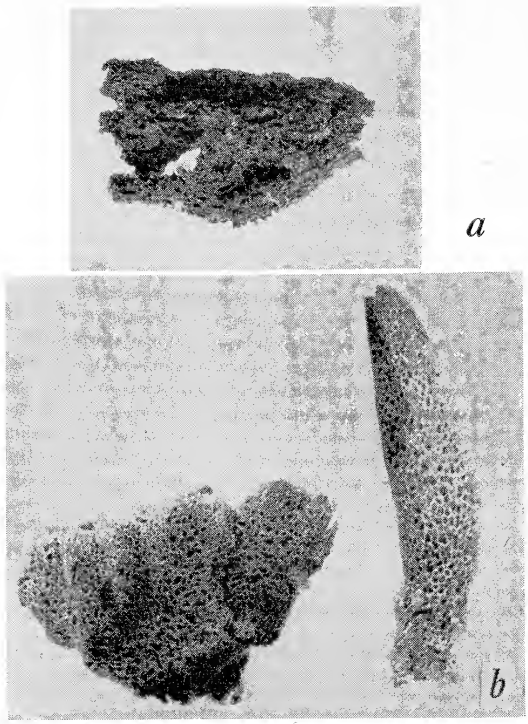


FIG. 1. *a, Ircinia novae zealandiae,* sp. nov. *b, Dysidea cristagalli,* sp. nov.

ORDER **HAPLOSCLERINA** (Topsent)

FAMILY HALICLONIDAE (de Laubenfels)

GENUS *Haliclona* (Grant)

Haliclona isodictyale, sp. nov.
Fig. 2*a, b*

OCCURRENCE: Waitawa Bay, Clevedon, 31/10/35 (coll. L. B. Moore). Waitawa Bay, Clevedon, 2/10/58. Point Chevalier Reef, 6/7/57.

DESCRIPTION: This sponge is an encrusting form with a maximum thickness of 3 mm. Its surface is minutely shaggy and hispid. The oscules are apical on tubular processes, as is characteristic of many haliclonids. The texture is soft and friable. In life the colour is pale cream, in spirit pale brownish-white. The skeleton is a subregularly-isodictyal reticulation, mainly unispicular.

Spicules. Megascleres: oxea .13 mm. × .007 mm. Microscleres: absent.

Haliclona tenacior, sp. nov.
Fig. 3*a, b*

OCCURRENCE: Waitawa Bay, Clevedon, on rocks or seaweed. Rangitoto, on rocks.

DESCRIPTION: An encrusting to irregularly massive sponge infested with commensal polychaete worms. Its surface is uneven, minutely and irregularly subpapillose. Oscula are few and inconspicuous. Texture is firm and friable. The colour in life is dirty-muddy cream, in spirit

FIG. 2. *a, Haliclona isodictyale,* sp. nov. *b, Haliclona isodictyale,* typical oxea (× 350).

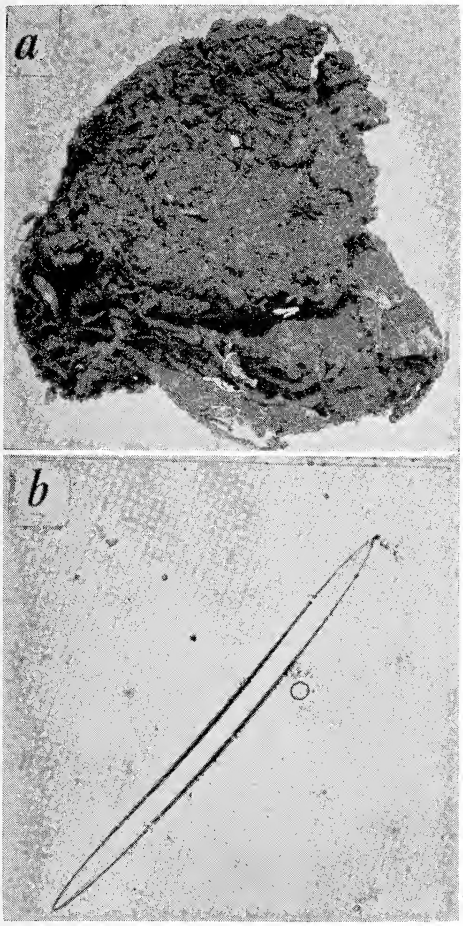


FIG. 3. *a, Haliclona tenacior,* sp. nov. *b, Haliclona tenacior,* typical oxea (× 350).

light greenish-brown. The skeleton is a closely knit reticulation of systems of fibres ranging from uni- to multispicular.

Spicules. Megascleres: oxea .14 mm. × .007 mm. Microscleres: absent.

Haliclona glabra, sp. nov.
Fig. 4

OCCURRENCE: Stanley Bay, under sides of boulders at low tidal levels.

DESCRIPTION: A thinly encrusting sponge with even, minutely hispid surface. The oscules are few, minute, and scattered. Texture is firm and friable. Colour in life is dull cream, in spirit pale brownish-white. The skeleton is an isodictyal reticulation, the ascending fibres of which are triangular. Connectives are unispicular.

Spicules. Megascleres: oxea .152 mm. × .007 mm. Microscleres: absent.

Haliclona heterofibrosa (Lundbeck)

Reniera heterofibrosa Lundbeck, 1902, p. 47, pls. 2, 11, figs. 8, 14; Brøndsted, 1923, p. 121; Hentschel, 1929, p. 983.

OCCURRENCE: Rangitoto Island. Point Chevalier Reef. Under sides of stones up to half tide.

REMARKS: Quite typical specimens, soft texture, ranging in colour from creamy yellow to faintly purple.

DISTRIBUTION: Arctic; Campbell Islands Subantarctic.

Haliclona clathrata (Dendy)

Reniera clathrata Dendy, 1895, p. 237; Brøndsted, 1923, p. 125; 1924*a*, p. 453); ? *R.* spec. 4, Hentschel, 1912, p. 410.

OCCURRENCE: Karaka Bay (St. Helier's).

REMARKS: Single specimen collected agrees so closely in external form with the holotype of *H. clathrata* (Dendy) that there seems every reason to refer it to this species. Structure of the skeleton is closely similar.

AUSTRALIA	N. Z.	CAMPBELL IS.	N. Z. (Br.)
Oxea .083 × .005 mm.	.157 × .007 mm.	.085–.115 × .005 mm.	.09–.105 × .004 to .006 mm.

This species appears to be a typical haliclonid insofar as the spicule sizes vary from specimen

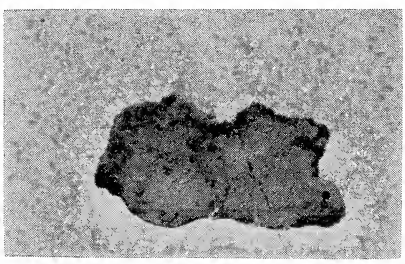


FIG. 4. *Haliclona glabra,* sp. nov.

to specimen. Small variations in this respect cannot be considered grounds for differentiating the present specimen from *H. clathrata.*

DISTRIBUTION: Australia (south coast); New Zealand; Campbell Islands.

Haliclona petrosioides (Burton)

Haliclona petrosioides Burton, 1932, p. 269, fig. 7.

OCCURRENCE: Rangitoto sublittoral fringe.

REMARKS: Specimens are thinly encrusting, up to 3 mm. thick, deep cream in colour. Surface conspicuously porose with conspicuous channels radiating in a stellate manner from small ill-defined oscules. The spiculation is identical with that of the holotype.

DISTRIBUTION: Tristan da Cunha (South Atlantic).

FAMILY CALLYSPONGIDAE (de Laubenfels)

GENUS *Callyspongia* (Duchassaing & Michelotti)

Callyspongia ramosa (Gray)

Synonymy: See Burton, 1934, p. 603.

OCCURRENCE: Noises Islands; Kawau Island; Narrow Neck.

REMARKS: An erect branching sponge, purple in life. Commonly washed up on Auckland beaches.

DISTRIBUTION: New Zealand; Australia; Antarctica.

ORDER **POECILOSCLERINA** (Topsent)

GROUP PHORBASIFORMES (de Laubenfels)

FAMILY PHORBASIDAE (de Laubenfels)

GENUS *Phorbas* (Duchassaing & Michelotti)

Phorbas intermedia, sp. nov.
Fig. 5*a, b*

OCCURRENCE: Rangitoto; Karaka Bay (St. Helier's).

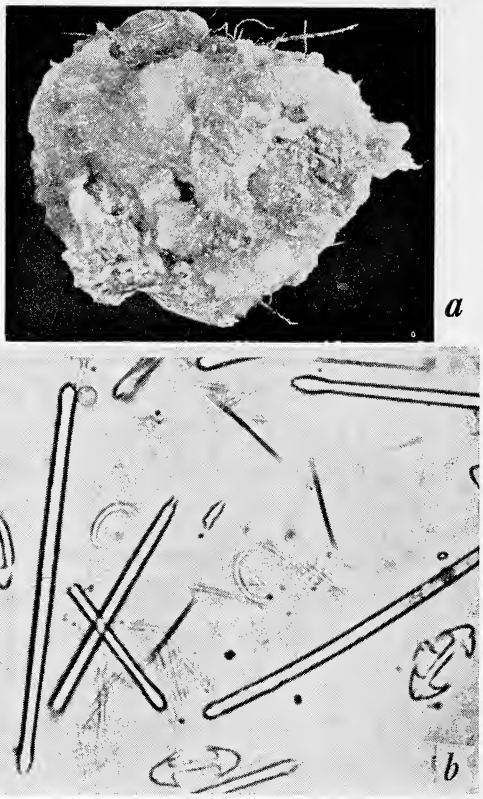


FIG. 5. *a, Phorbas intermedia,* sp. nov. *b, Phorbas intermedia,* acanthotornota, acanthostyles, isochelae, sigmata, raphides (× 350).

DESCRIPTION: An irregularly massive sponge with an uneven to minutely papillate surface. Oscula are not apparent. The texture is firm. Colour in life is a rich yellow, in spirit a pale yellow. The skeleton, a confused system of ascending fibres branching and anastomosing, is composed of bundles of acanthostyli of two sizes and tornota. There is a dermal palisade of brushes of tornota.

Spicules. Megascleres: (a) acanthostyles .17 to .22 mm. × .005 to .007 mm.; (b) acanthostyles .09 × .004 mm.; (c) tornota with subtylote microspined ends—.15 × .004 to .006 mm. There are numerous intermediates between acanthostyli and tornota. Microscleres: (a) arcuate isochelae .04 × .045 mm. chord; (b) sigmata .017 × .021 mm. chord; (c) raphides .04 × .07 mm. long.

FAMILY ADOCIIDAE (de Laubenfels)

GENUS *Adocia* (Gray)

Adocia parietalioides, sp. nov.
Fig. 6*a, b*

OCCURRENCE: Rangitoto Island; littoral.

DESCRIPTION: An encrusting sponge with even, porose surface. Oscules small, 1–2 mm. in diameter, few in number, and level with the surface. Texture firm and friable. Colour in life faintly pink, in spirit pale brownish white. Main and dermal skeletons unispicular.

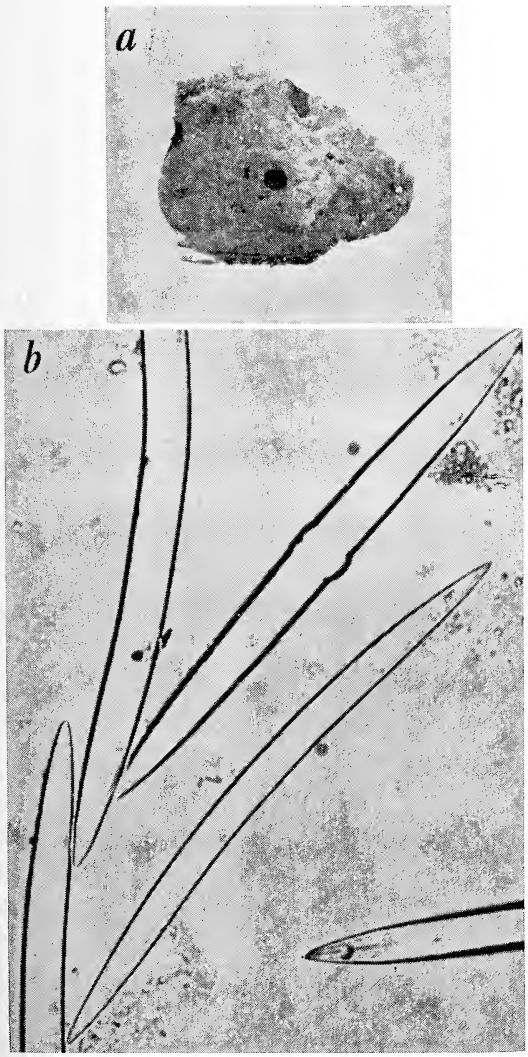


FIG. 6. *a, Adocia parietalioides,* sp. nov. *b, Adocia parietalioides,* typical oxea (× 350).

Spicules. Megascleres: oxea .15 × .01 mm. Microscleres: absent.

REMARKS: This species is most closely related to *A. parietalis* (Topsent) from the Mediterranean, from which species it differs in: (a) the absence of subdermal canals radiating from the oscules; (b) the character of the undersurface of the free edges (which in *A. parietalis* "releve . . . et y developpe a sa face inferieure un feutrage plus serre des spicules . . ."); (c) the size of the oxea, which are .01 mm. in thickness, as opposed to .005 mm. in *A. parietalis.*

Adocia venustina, sp. nov.
Fig. 7*a, b*

OCCURRENCE: Noises Islands, in mouth of cave; Rangitoto, in mouth of cave.

DESCRIPTION: A sponge ranging in habit from encrusting to massive and depressed. Surface is uneven and glabrous. Oscules are numerous, subpapillate, 1–3 mm. in diameter. This sponge is of firm, friable texture. Colour in life yellow, in spirit dull yellowish brown. The main skeleton is isodictyal or sub-isodictyal, chiefly unispicular, but having occasional bispicular ascending fibres. The dermal skeleton is unispicular with mainly triangular mesh.

Spicules. Megascleres: oxea .1 × .004 mm. Microscleres: absent.

GENUS *Toxadocia* (de Laubenfels)

Toxadocia toxophorus (Hentschel)

Gellius toxophorus Hentschel, 1912, p. 392, pl. 21, fig. 46.

Gellius toxotes Hentschel, 1912, p. 392, pl. 21, fig. 47.

OCCURRENCE: Rangitoto sublittoral fringe.

REMARKS: The species is represented by cushion-shaped masses up to 1 cm. thick, pale cream in colour, with firm uneven surfaces. The oscules are scattered, 1–2 mm. in diameter. Skeleton is a loose subhalichondroid reticulation, mainly unispicular, of oxea tending to be

strongylote, .24 × .014 mm., and with toxa .035 to .052 mm. long, for microscleres.

The old genus *Gellius* has been split by de Laubenfels (1936) into several genera and the present species is referred to *Toxadocia.*

DISTRIBUTION: Aru Islands (Malay Archipelago), 4–6 fathoms.

GROUP MICROCIONIFORMES (de Laubenfels)

FAMILY MICROCIONIDAE (Hentschel)

GENUS *Microciona* (Bowerbank)

Microciona coccinea, sp. nov.
Fig. 8*a, b*

OCCURRENCE: Stanley Bay, under sides of stones at low tide. Onetangi, Waiheke Island, on roof of cave at low tide.

DESCRIPTION: A thinly encrusting sponge with uneven surface over which oscula are not apparent. Texture is soft. Colour when alive is scarlet, in spirit rusty brown. The skeleton is low plumose columns of basally spined styli and of acanthostyli. Scattered loose between the columns and forming a loose tangential layer in the dermis are auxiliary subtylostyli.

Spicules. Megascleres: (a) basally spined styli .24 to .4 × .012 to .016 mm.; (b) acanthostyli .08 to .21 × .007 to .014 mm.; (c) subtylostyli .14 to .28 × .003 to .004 mm. Microscleres: toxas .05 to .07 mm. chord.

Microciona rubens, sp. nov.
Fig. 9*a, b*

OCCURRENCE: Waitawa Bay, Clevedon, encrusting rocks at 2 fathoms.

DESCRIPTION: An encrusting sponge with an uneven, minutely and irregularly mammilate surface on which oscules are not apparent. Texture firm. Colour in life vermillion red, in spirit pale brownish yellow to dark brown. The skeleton is made up of plumose columns of basally spined styli (rarely completely smooth) and of acanthostyli. Auxiliary subtylostyli are associated with these columns and form an irregular tangential layer in the dermis.

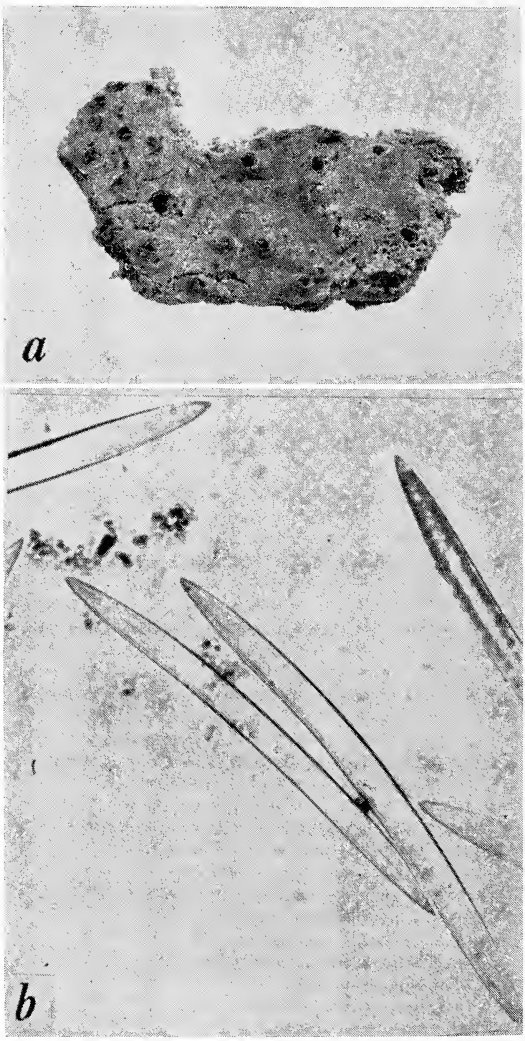


FIG. 7. *a, Adocia venustina,* sp. nov. *b, Adocia venustina,* typical oxea (× 350).

Spicules. Megascleres: (a) basally spined styli .14 to .53 × .021 mm.; (b) acanthostyli .09 × .011 mm.; (c) subtylostyli .11 to .28 × .003 to .005 mm. Microscleres: (a) palmate isochelae .008 mm. chord; (b) toxa .04 to .07 mm. chord.

REMARKS: This species is most closely related to *Clathria mortensenii* (Brøndsted), which has been transferred to *Microciona* by de Laubenfels (1936). Spicule dimensions in the present specimens differ widely from those described by Brøndsted.

Microciona heterospiculata (Brøndsted)

M. heterospiculata Brøndsted, 1924*a*, p. 465, fig. 20.

OCCURRENCE: Point Chevalier Reef; Karaka Bay; Stanley Bay. Up to half tide encrusting rocks.

DISTRIBUTION: New Zealand.

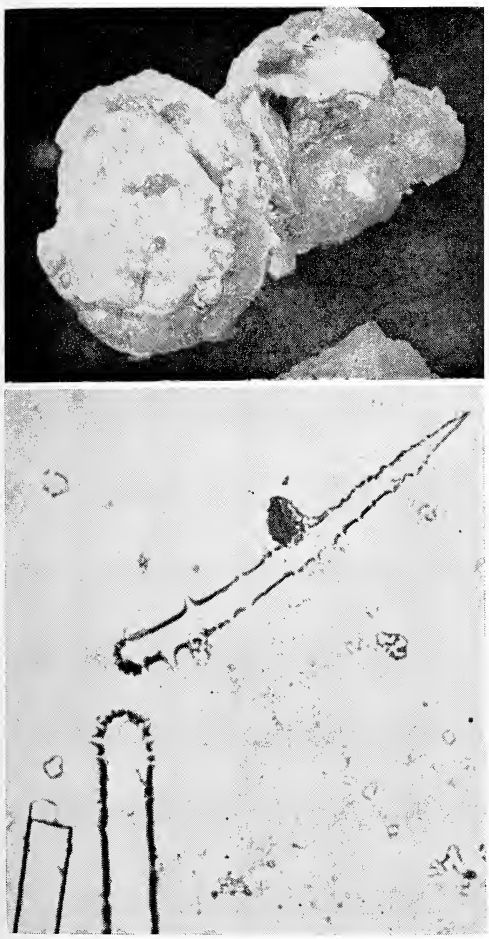


FIG. 8. *a, Microciona coccinea,* sp. nov. *b, Microciona coccinea,* acanthostyle, basally spined style.

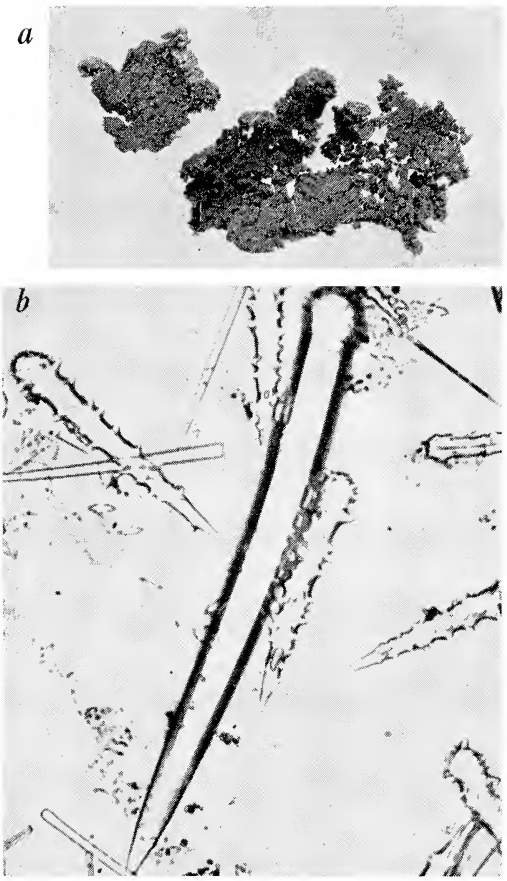


FIG. 9. *a, Microciona rubens,* sp. nov. *b, Microciona rubens,* spined style, acanthostyles, subtylostyle, isochelae (× 350).

FAMILY OPHLITASPONGIIDAE (de Laubenfels)

GENUS *Mycale* (Gray)

Mycale rara (Dendy)

Esperella rara Dendy, 1896, p. 18.

OCCURRENCE: Ahipara Bay.

REMARKS: The one specimen, yellow and soft in life, agrees closely with Dendy's original specimen, except that trichodragmata appear to be absent. Occasional isochelae .017 mm. chord occur.

DISTRIBUTION: Australia.

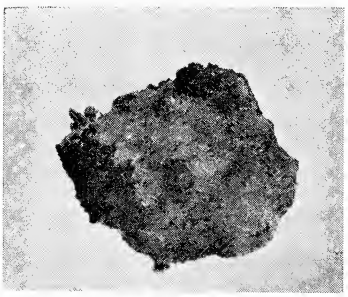
FAMILY AMPHILECTIDAE (de Laubenfels)

GENUS *Biemna* (Gray)

Biemna rhabderemioides, sp. nov.
Fig. 10*a, b*

OCCURRENCE: Rangitoto, under stones at about half tide.

DESCRIPTION: An encrusting to massive and low-lying sponge, the surface of which is minutely reticulate, conulose, and hispid. The oscules are not apparent. Texture is firm. Colour in life bright yellow, in spirit pale yellowish-brown. The skeleton is an irregular reticulation of styli and subtylostyli bent in the basal third and crooked at the proximal end.



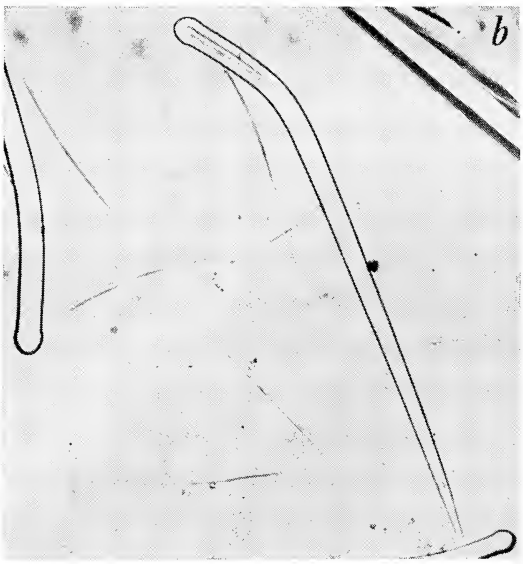
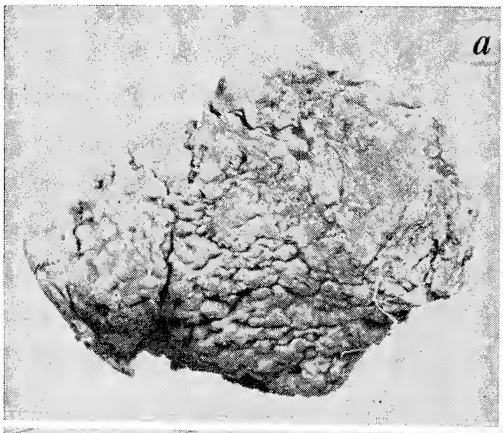


FIG. 10. *a, Biemna rhabderemioides,* sp. nov. *b, Biemna rhabderemioides,* subtylostyli, raphides (× 350).



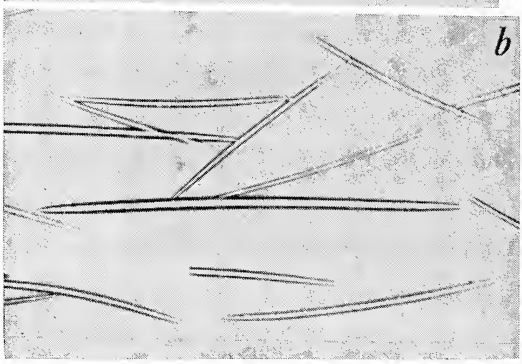


FIG. 11. *a, Halichondria moorei,* sp. nov. *b, Halichondria moorei,* oxea (× 80).

Spicules. Megascleres: (a) styli .42 to .47 × .01 to .016 mm.; (b) subtylostyli .42 to .48 × .01 to .016 mm. Microscleres: (a) sigmata (two sizes) .042 to .045 and .012 to .014 mm. chord; (b) raphides .09 mm. long; (c) microxea .05 × .003 mm.

ORDER **HALICHONDRINA** (Vosmaer)

FAMILY HALICHONDRIIDAE (Gray)

GENUS *Halichondria* (Fleming)

Halichondria moorei, sp. nov.
Fig. 11*a, b*

OCCURRENCE: Point Chevalier Reef; Karaka Bay (St. Helier's); Parnell Reef.

DESCRIPTION: A massive, somewhat depressed sponge with surface wrinkled and irregularly folded. Oscula not apparent. Colour alive pinkish-

orange (Munsell, rY–R 7/8), in spirit nearly white. Both main and dermal skeletons typical for the genus.

Spicules. Megascleres: oxea .3 to .8 × .005 to .017 mm. Microscleres: absent.

REMARKS: The tissues of this sponge are so heavily filled with opaque pigment cells that it is possible to study the arrangement of the skeleton only with the utmost difficulty.

Halichondria panicea (Pallas)

Spongia panicea Pallas, 1766, p. 388.
Halichondria panicea Johnston, 1842, p. 114.

OCCURRENCE: Point Chevalier Reef.

DISTRIBUTION: Arctic; Atlantic coasts of Europe and North America; Mediterranean; Azores; South Africa; Antarctic; New Zealand; extreme southern shores of South America; Japan; Sea of Japan.

FAMILY HYMENIACIDONIDAE (de Laubenfels)

GENUS *Hymeniacidon* (Bowerbank)

Hymeniacidon perlevis (Montague)

Spongia perlevis (Montague, 1818, p. 86) = *H. sanguinea* (Grant) and *H. caruncula* (Bowerbank).

OCCURRENCE: Waitawa Bay, Clevedon; Anawhata; Stanley Bay. Lower midlittoral.

REMARKS: Bright orange-yellow, tending toward orange when in shadow. The earlier name, *H. perlevis* (Montague), almost entirely overlooked in the literature, must take precedence over the more familiar names.

DISTRIBUTION: Arctic; Atlantic coast of Europe; Mediterranean; West Africa; South Africa; Australia; New Zealand; Japan.

FAMILY AXINELLIDAE (Ridley and Dendy)
SUBFAMILY AXINELLINAE (de Laubenfels)

GENUS *Axiamon* (Hallman)

Axiamon erecta (Brøndsted)
Fig. 12

Hymeniacidon erecta Brøndsted, 1924*a*, p. 479, fig. 32.

OCCURRENCE: Kawau Island. Commonly washed up on Auckland beaches.

REMARKS: Two of Brøndsted's species of *Hymenacidon, novae zealandiae* and *erecta,* were relegated to *Axiamon* by de Laubenfels (1936: 130). This species has never before been figured, and therefore a photograph is appended.

DISTRIBUTION: New Zealand.

ORDER HADROMERINA (Topsent)
FAMILY CHOANITIDAE (de Laubenfels)
SUBFAMILY CHOANITINAE (de Laubenfels)

GENUS *Rhabderemia* (Topsent)

Rhabderemia stellata, sp. nov.
Fig. 13*a, b, c*

OCCURRENCE: Rangitoto Island, under stones at low tide.

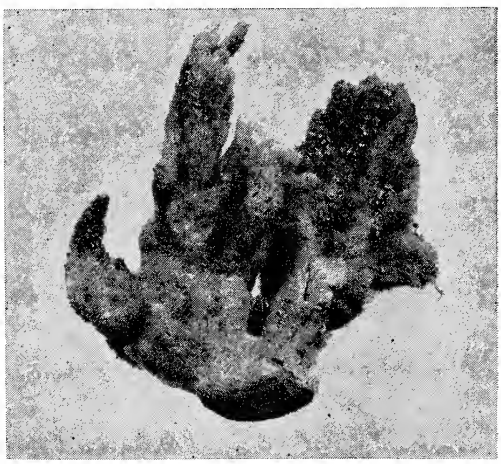


FIG. 12. *Axiamon erecta* (Brøndsted).

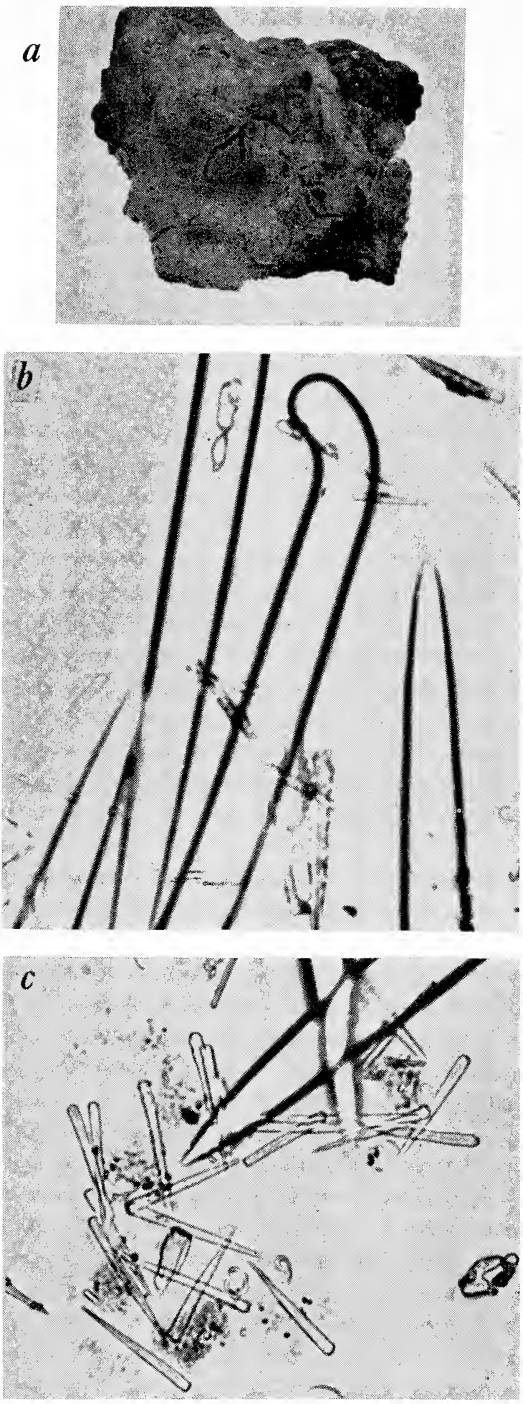


FIG. 13. *a, Rhabderemia stellata,* sp. nov. *b, Rhabderemia stellata,* rhabdostyles, acanthostyli (× 350). *c, Rhabderemia stellata,* contorted sigmas (× 350).

DESCRIPTION: An encrusting sponge with porose surface copiously marked by subdermal grooves. Oscules are small, sometimes the grooves radiate in stellate manner from them. Colour in life yellow, in spirit pale brown. The skeleton is a reticulation with subplumose ascending fibres and connectives, mainly unispicular, of rhabdostyli.

Spicules. Megascleres: rhabdostyles .21 to .32 × .015 to .021 mm. Microscleres: (a) acanthostyli .039 to .045 × .003 to .004 mm.; (b) much-contorted sigmas .011 to .017 mm. chord; (c) quadriradiate spicules (calthrops?) with rays .014 to .024 mm. (These are found occasionally in a subdermal position and appear to be foreign inclusions.)

FAMILY SUBERITIDAE (Schmidt)

GENUS *Suberites* (Nardo)

Suberites cupuloides, sp. nov.
Fig. 14*a, b*

OCCURRENCE: Rangitoto, littoral in swiftly flowing water. Onetangi Beach in similar habitat.

DESCRIPTION: A massive sponge with large rounded lobes. The surface is even and minutely hispid. Oscules are not apparent. The texture is firm and fleshy. Colour in life is yellowish-scarlet, in spirit yellowish-brown. The skeleton is of loose, subplumose ascending fibres, ending at the surface in paniculate brushes. Megascleres are of two distinct sizes, the smaller occurring mainly in the dermal brushes.

Spicules. Megascleres: tylostyli .17 to 8 × .011 to .018 mm. Microscleres: absent.

GENUS *Isociella* (Hallmann)

Isociella incrustans, sp. nov.
Fig. 15*a, b*

OCCURRENCE: Ahipara Bay, on ledge under rocks at low tide.

DESCRIPTION: This sponge ranges in form from encrusting to massive and spreading. Its surface is uneven and minutely mammillate. Oscules are small, scattered or irregularly grouped. Often with radiating subdermal channels. The texture is firm and resilient. Colour in life scar-

let, in spirit whitish. The skeleton is an irregular reticulation of fibres cored and quasi-echinated by main styli (often subtylostylote) of two sizes. Auxiliary subtylostyli of two sizes present. Dermal skeleton is a tangential layer of larger subtylostyli echinated by a palisade of smaller subtylostyli.

Spicules. Megascleres: (a) main styli (2 sizes): .32 to .35 × .013 to .014 mm.; .2 to .24 × .007 to .011 mm.; (b) auxiliary subtylostyli (2 sizes): .28 to .34 × .007 to .011 mm.; .14 to .23 × .003 to .006 mm. Microscleres: palmate isochelae .011 to .014 mm. chord.

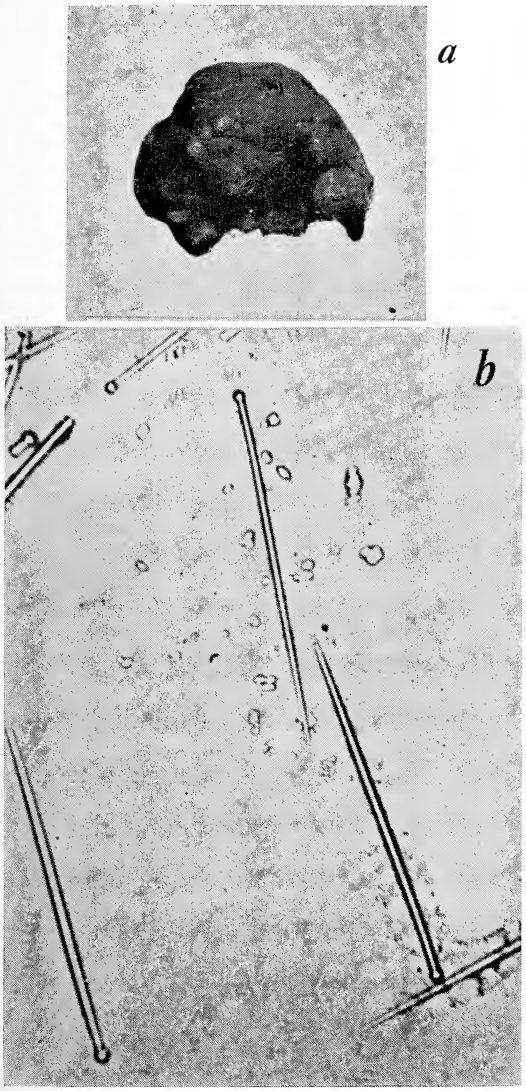


FIG. 14. *a, Suberites cupuloides,* sp. nov. *b, Suberites cupuloides,* tylostyli (× 350).

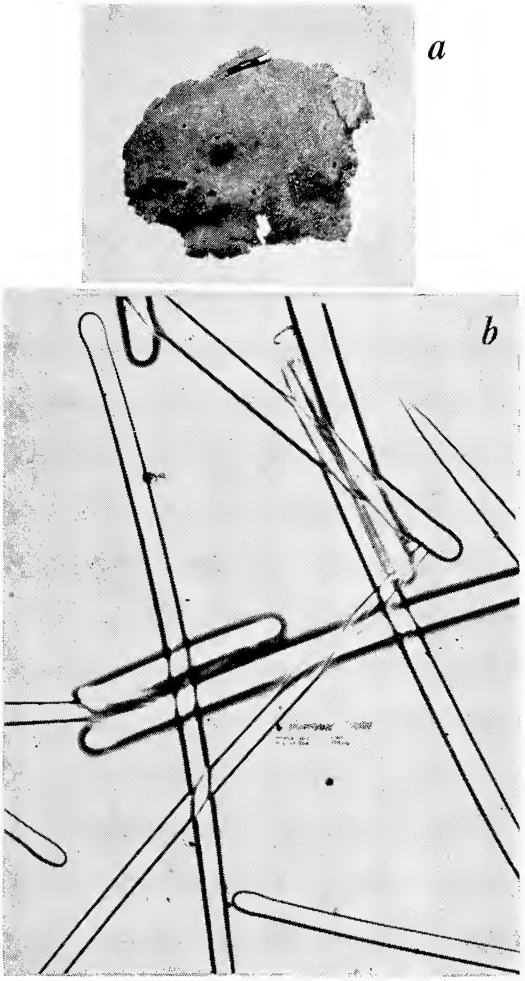


FIG. 15. *a, Isociella incrustans,* sp. nov. *b, Isociella incrustans,* styli, subtylostyli, isochelae (× 350).

GENUS *Polymastia* (Bowerbank)

Polymastia fusca, sp. nov.
Fig. 16*a, b*

OCCURRENCE: Burgess Bay, Kawau Island, under rock ledge. Ahipara Bay, under rock ledge. Spirits Bay, under rock ledge.

DESCRIPTION: A massive, spreading sponge, with numerous low wartlike papillae. Surface is even and minutely hispid. The oscules are small, apical on the papillae. The texture is firm and

fleshy. Colour in life greenish to chocolate brown (Munsell, rY–R 8/4), in spirit pale brown. The skeleton is of stout radiating bundles of large subtylostyli, with medium-size and small subtylostyli scattered thickly in the choanosome and forming a dense subdermal layer. The dermal skeleton is a palisade of mainly small subtylostyli.

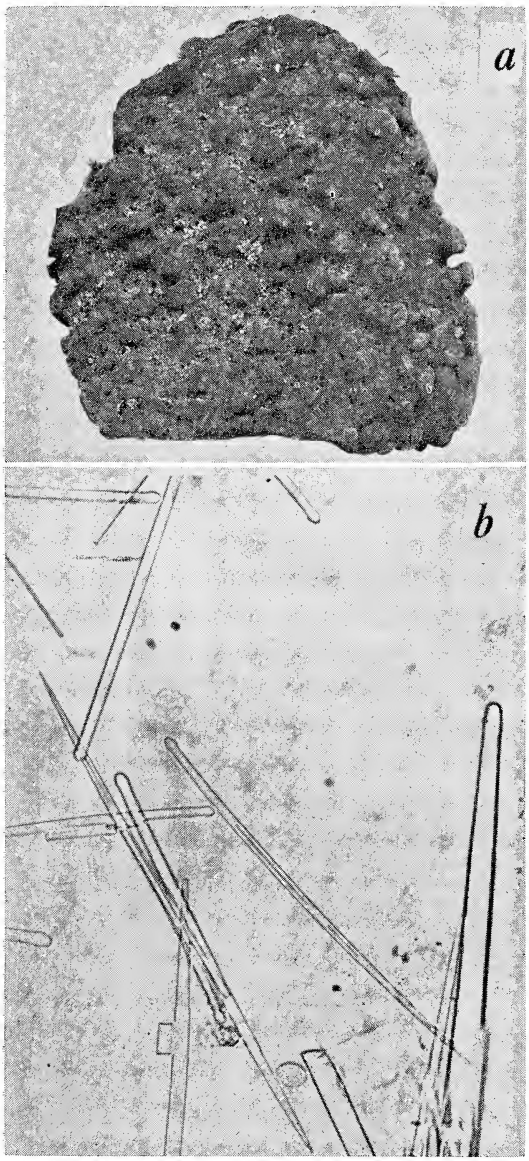


FIG. 16. *a, Polymastia fusca,* sp. nov. *b, Polymastia fusca,* subtylostyli (× 350).

Spicules. Megascleres: subtylostyli of three sizes: (a) .64 × .011 mm.; (b) .4 to .48 × .008 mm.; (c) .14 × .004 mm.

Polymastia granulosa (Brøndsted)

Polymastia granulosa Brøndsted, 1923, p. 162, fig. 36.

OCCURRENCE: Anawhata, Piha; lower midlittoral.

REMARKS: Colour bright yellow.

DISTRIBUTION: Auckland Islands; Subantarctic.

GENUS *Aaptos* (Gray)

Aaptos aaptos (Schmidt)

Synonymy: See Dendy and Frederick, 1924, p. 508.

OCCURRENCE: Stanley Bay; lower midlittoral.

REMARKS: Specimens all typically reddish-purple externally, brownish-yellow internally.

DISTRIBUTION: Mediterranean; West Indies; Indian Ocean; Malaya; Australia.

FAMILY CLIONIDAE (Gray)

GENUS *Cliona* (Grant)

Cliona celata (Grant)

Cliona celata Grant, 1826, p. 79.

OCCURRENCE: Point Chevalier; Kawau Island; Piha. Midlittoral.

DISTRIBUTION: Arctic; Atlantic coasts of Europe and North America; West Indies; Indian Ocean; Malaya; Australia.

Cliona muscoides (Hancock)

Cliona muscoides Hancock, 1849, p. 335, pl. 15, fig. 11.

OCCURRENCE: Spirits Bay at 4 fathoms.

REMARKS: The habit of the present specimen, especially the appearance of its perforations at the surface of the shell, conforms closely with

Hancock's description. The spicules are identical in appearance, save that the oxea are faintly microspined; the measurements differ, however.

	CHILE	NEW ZEALAND
Tylostyli...	.18 mm. long	.1 to .12 × .003 mm.
Oxea.....	.07 mm. long	.052 to .07 × .003 mm.

A difference between the present specimen and the holotype is the presence in the New Zealand sponge of small spiny microrhabds, .007 × .002 mm. No mention is made of these in the holotype. Their distribution is, however, sparse and irregular; they themselves are inconspicuous and could easily have been overlooked. The holotype had infested a shell of *Monoceras fusoides,* a species recorded for Chile only. Other species of Mollusca are common to Chile and New Zealand, and there is no reason to suppose the *Cliona* should not share this wide distribution.

DISTRIBUTION: Chile.

ORDER CARNOSA (Carter)

FAMILY HALINIDAE (de Laubenfels)

SUBFAMILY CORTICIINAE (Vosmaer)

GENUS *Corticella* (Sollas)

Corticella novae-zealandiae, sp. nov.
Fig. 17*a, b, c*

GENOTYPE: *Corticum stelligerum* Schmidt, 1868, p. 25, pl. 3, fig. 6.
Corticella stelligera Sollas, 1888, p. 281.

OCCURRENCE: Rangitoto Island; sublittoral fringe.

DESCRIPTION: An encrusting to massive and depressed sponge, its surface smooth but uneven. Oscules never apparent. The texture is firm and granular. Colour in life white, in spirit pale brown.

Spicules. Megascleres: calthrops, rays .12 to .21 mm. × .026 to .038 mm. The number of rays may sometimes be multiplied to 5 and 6 and some can show a slight dicho-modification. Microscleres: (a) strongylasters .011 mm. in diameter; (b) oxyasters, 5–7 rays .05 to .07 mm. in diameter.

REMARKS: This specimen differs from the only other known species from the Mediterranean in the dimensions of the spicules.

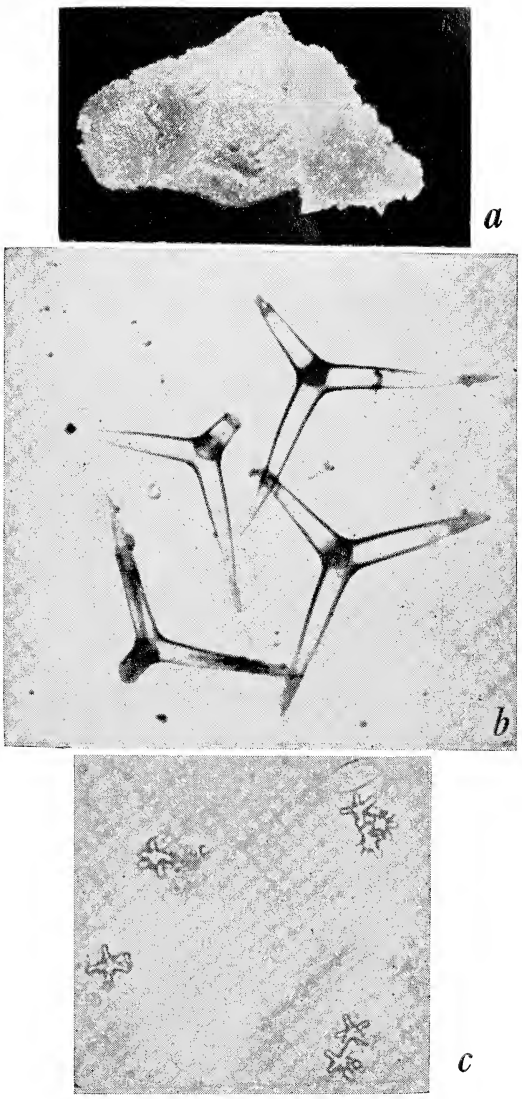


FIG. 17. *a, Corticella novae-zealandiae,* sp. nov. *b, Corticella novae-zealandiae,* typical calthrops (× 80). *c, Corticella novae-zealandiae,* strongylasters (× 350).

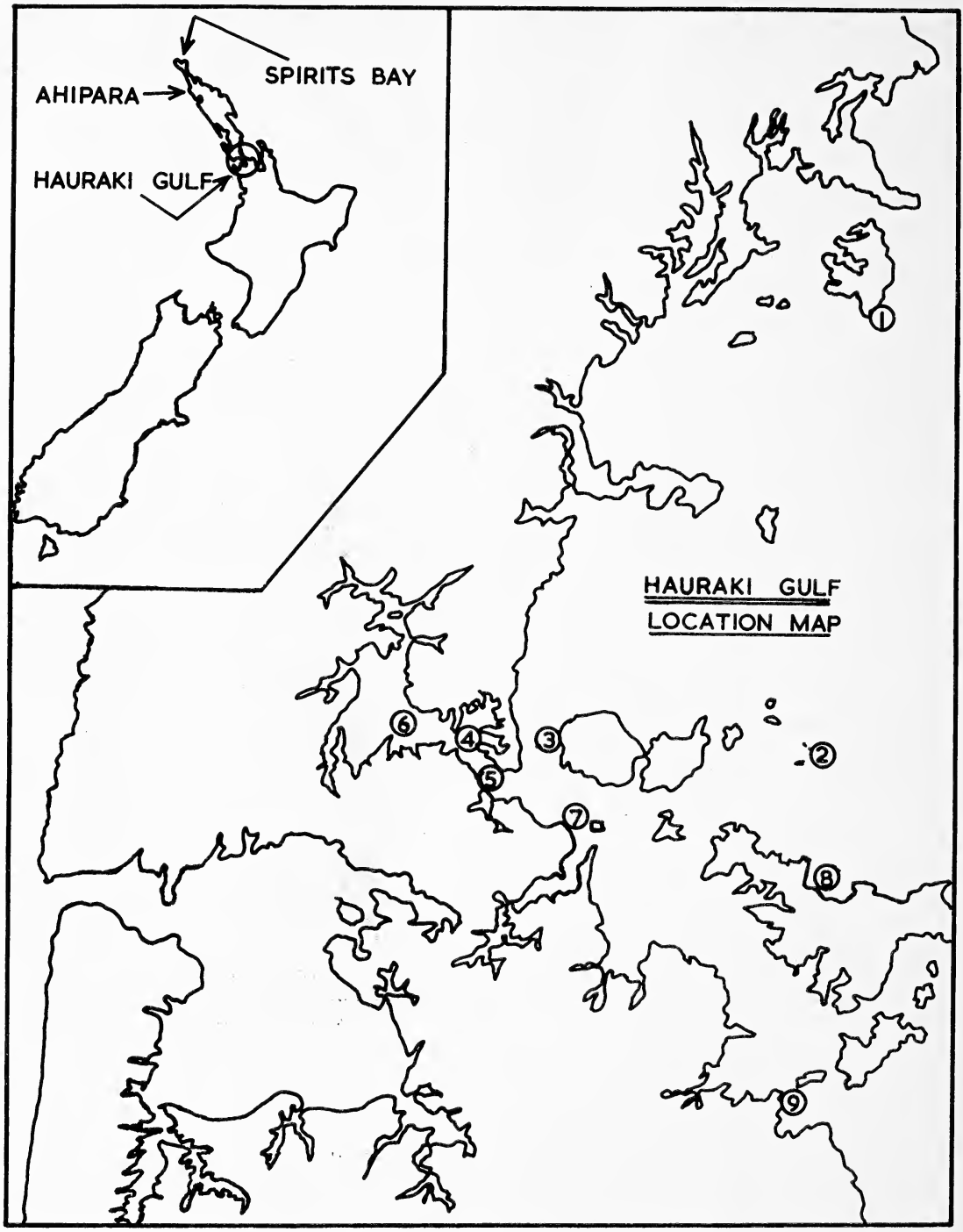


FIG. 18. Location map of Hauraki Gulf (New Zealand inset).

Legend: *1*, Burgess Bay, Kawau; *2*, Noises Islands; *3*, Rangitoto; *4*, Stanley Bay; *5*, Parnell Reef; *6*, Point Chevalier Reef; *7*, Karaka Bay, St. Helier's; *8*, Onetangi, Waiheke; *9*, Waitawa Bay, Clevedon.

GENUS *Plakina* (Schulze)

Plakina monolopha (Schulze)

Synonymy: See Burton, 1929, p. 414.

OCCURRENCE: Rangitoto; midlittoral.

REMARKS: A small yellow incrustation.

DISTRIBUTION: Mediterranean; Atlantic coast of France; West Indies; Antarctic; Japan.

Plakina trilopha (Schulze)

Synonymy: See Burton, 1929, p. 414.

OCCURRENCE: Rangitoto; midlittoral.

REMARKS: A small incrustation, cream to deep purple.

DISTRIBUTION: Mediterranean; Antarctic.

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Effects of Pollution on the Free Amino Acid Content of Two Marine Invertebrates

RITA D. SCHAFER[1]

RECENT REPORTS have been received from some inhabitants of the southern California coastal area of a change in the texture and taste of certain edible marine invertebrates. Investigation showed that the specimens so designated had been taken from areas known to be polluted. The term "polluted" as used here has been given the same meaning as that used in the ecological study by Reish (1956) on the San Gabriel River area: this meaning is the dictionary definition, "the act of making or rendering unclean."

It has been shown for some invertebrates that a change in environmental factors will produce a change in either histological or morphological composition. Kinne (1958) showed that a change in ectodermal cell shape can be induced in *Cordylophora craspia* by varying the environment from marine to brackish. Wilson and Armstrong (1958), after experimentation, concluded that *Echinus* eggs and larvae are affected structurally by the properties of sea water. It has also been demonstrated (Lane and Schafer, in progress) that a difference in diet may change the amino acid composition of muscle tissue in some invertebrates. Since this is known to be true under controlled conditions, the possibility exists that a variation in tissue composition might occur as a result of a polluted and consequently altered environment.

This study was thus undertaken to determine (1) if the change in appearance and taste was accompanied by a change in amino acid composition, and (2) the nature of the change, if one had occurred.

Acknowledgments. The author is indebted to Dr. Norman Mattox of the Department of Biology, University of Southern California, for his direction and valuable suggestions throughout the course of this investigation, and to the administration of the Allan Hancock Foundation for the use of laboratory facilities. She also wishes to express her thanks to Mr. Fred Ziesenhenne of the Allan Hancock Foundation and to Mr. John Fitch of the California Department of Fish and Game, for the collections of specimens from the islands; and to Dr. Donald Reish for the use of his data of measured oxygen from the Los Angeles Harbor area. This study was supported by a research grant from the United States Public Health Service of the National Institute of Health, no. RG-4911.

[1] Allan Hancock Foundation, University of Southern California, Los Angeles. Manuscript received July 8, 1959.

MATERIALS AND METHODS

The animals used for investigation were the abalone, *Haliotis cracherodii* Leach, and the crab, *Pachygrapsus crassipes* Randall. The abalone was selected for study, as it is the form in which the greatest difference in tissue texture and taste has been observed. *P. crassipes* was selected because of its wide distribution and marked tolerance of polluted conditions. These two forms also offer two extremes as to length of time in which the animals are directly subjected to the polluted water. *Haliotis* is exposed to the air only during periods of lower low tides and therefore is almost continuously within the influence of the conditions prevailing in the polluted water. *Pachygrapsus,* on the contrary, lives in the high tide zone along a rocky shore or on floats rather than in the water in a wharf region and consequently is submerged only during periods of high tide, and is directly subjected to the pollutants for comparatively less time than is the abalone. Collections were made from polluted waters and, for a basis of comparison, from waters known to be free of pollution.

Specimens of *Haliotis* were collected along the shore at White's Point in the Palos Verde region of the southern California coast, from San Clemente Island, Anacapa Island, and Santa

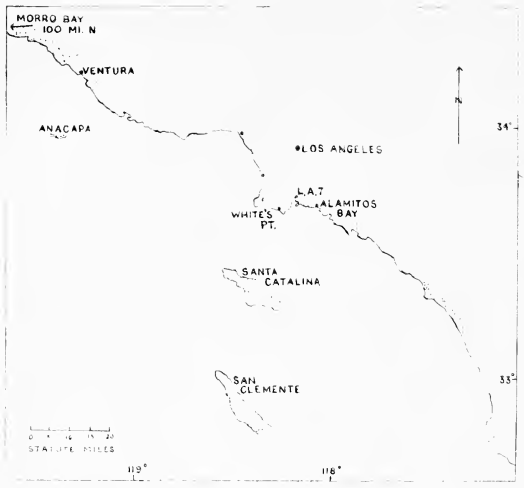

FIG. 1. Areas of collection.

Catalina Island. *Pachygrapsus crassipes* were collected from a point in the west channel of the Los Angeles Harbor area designated as L.A. 7, the mouth of the San Gabriel River at Alamitos Bay, White's Point, Santa Catalina Island, Anacapa Island, and Morro Bay (Fig. 1). White's Point, L.A. 7, and the mouth of the San Gabriel River at Alamitos Bay can be considered polluted areas; while Morro Bay, Santa Catalina Island, San Clemente Island, and Anacapa Island are surrounded by nonpolluted water. In the polluted areas both the nature and the degree of pollution vary.

White's Point is a sewer outfall area in which the pipes convey the treated sewage to a site 6,716 ft. from the shore line. According to Stephenson and Grady (1956), oxygen deficiency at 6,000–8,000 ft. from the outfall varied from 10–30 per cent, at one time of measurement, to 0 per cent (or normal) at another time. It was reported, further, that ammonia content was not normal in any area within 11,000 ft. of the outfall. Measurements taken at 3,000 ft. from the outfall showed an increase of silicates and phosphates. Although dilution undoubtedly occurs in the remaining 3,700 ft., it would not be safe to assume that the water in the intertidal area where the specimens were taken is of normal composition.

The White's Point area is divided at low tide into a northern cove and a southern cove by a narrow expanse of rock which extends out from shore for approximately 200 ft. A survey of the fauna of these two sections shows them to be quite different. On the southern side of the rocky projections were found scattered specimens of *Haliotis cracherodii,* an occasional *Pachygrapsus crassipes,* masses of the tubed worm, *Phragmatopoma californica,* and specimens of the limpets *Fissurella volcano* and *Acmaea limatula.* Empty *Olivella* shells were also present in relatively large numbers. In sharp contrast to this paucity of forms and individuals was the fauna of the northern section. Here were noted specimens of *Pisaster ochraceus, Strongylocentrotus purpuratus, S. franciscanus, Ophiothrix spiculata, Bulla gouldiana, Aplysia californica, Octopus bimaculatus, Conus californicus, Pagurus samuelis,* in addition to those animals found on the southern side. This difference can be explained by the fact that the sewer outfall opens offshore in a line with the rocky projection which separates the two sides. The current flows primarily from north to south carrying the polluted water in the direction of the southern section.

The point designated as L.A. 7 is located in the west channel of Los Angeles Harbor. The term "L.A. 7" was given to this particular point in a pollution survey conducted in 1952 by the Los Angeles Regional Water Pollution Control Board, and has been retained in this study so that this site may be recognized and related to data taken from that point. Specimens of *Pachygrapsus crassipes* tested were taken from the piling and floats at one of the small yacht harbors in this area. The nature of the pollution at this point has been designated as primarily raw sewage from approximately 500 persons. Oxygen content of the water, measured at monthly intervals over a period of 3 years (1956 through 1958), showed fluctuations from a low of 2.0 to a high of 8.2 parts per million. An ecological survey of the area shows the customary wharf fauna of the southern California waters. Anemones, the wharf mussel (*Mytilus edulis*), tunicates both solitary and colonial, hydroids, barnacles, and colonial serpulid worms are attached in great abundance to the underside of the wooden floats, while numerous speci-

mens of *Pachygrapsus crassipes* live on the floats and piling just above the water line. Since the area is maintained as a small yacht harbor, the floats are scraped occasionally and invariably are soon resettled by young forms of the species mentioned.

The conditions at the mouth of the San Gabriel River at Alamitos Bay were thoroughly investigated and reported by Reish in 1956. He reports the primary source of waste discharge into that region to be the Dow Chemical Company, the Santa Fe Springs Waste Disposal Company, two domestic sewage disposal plants, and the Los Angeles Bureau of Water and Power Steam Plant.

Since specimens of the same species living in the same conditions are known to have a consistent pattern of free amino acids in their muscle tissues, an investigation of these amino acids should indicate whether or not a change from a normal to an abnormal metabolism has taken place. An analysis of free amino acids was thus undertaken by means of two-dimensional paper chromatography.

Muscle tissue only was used for the determinations. All samples studied were taken from individual animals. Pooled samples were not used. Specimens were quick-frozen; muscle tissue from the foot of the abalone and from the legs of the crab was excised and subsequently lyophilized without thawing. This precaution was taken to inhibit the activity of autoenzymes and bacterial enzymes. After lyophilization the tissue was extracted with cold 70 per cent ethanol. Two 50 ml. aliquot portions were used, and extraction was permitted for at least 12

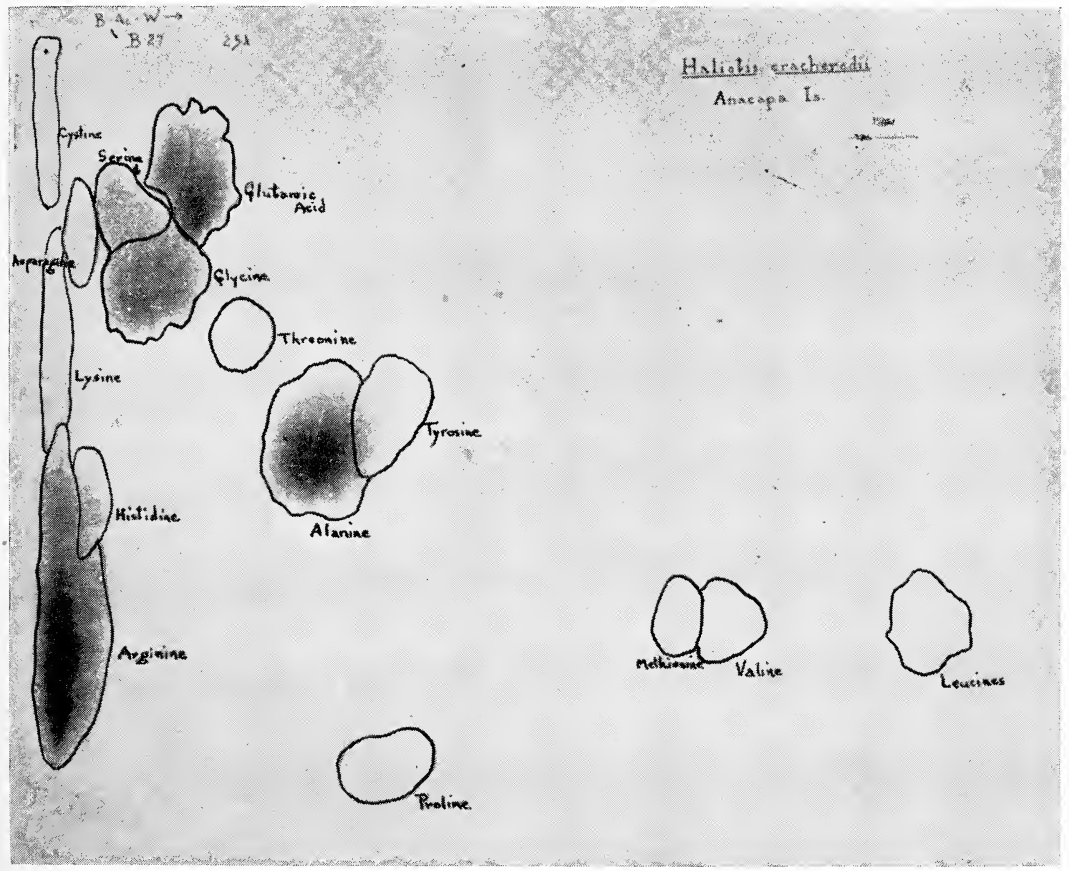

FIG. 2. Chromatogram of free amino acids of *Haliotis cracherodii* taken from Anacapa Island, a nonpolluted area.

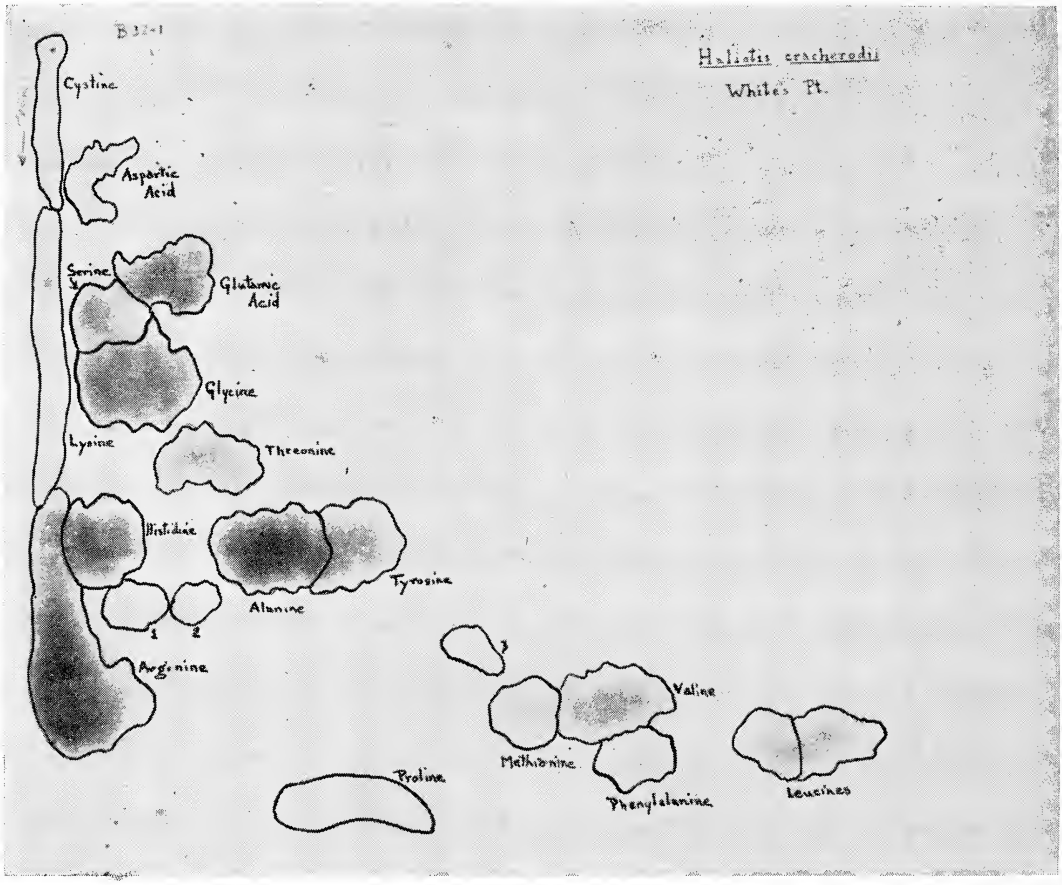

FIG. 3. Chromatogram of free amino acids of *Haliotis cracherodii* taken from White's Point, a polluted area.

hours for each portion. Extracts were then concentrated and stored under refrigeration as a 4.4 ml. solution of 10 per cent isopropanol.

Chromatograms were run on 18½- by 22¼-inch Whatman no. 1 filter papers. A mixture of butanol, acetic acid, and water (4:1:5) was used as the first phase; water-saturated phenol was used as the second. Development was carried out by dipping in a 0.2 per cent solution of ninhydrin in acetone.

RESULTS

The abalone, *Haliotis cracherodii,* from both polluted and nonpolluted areas contained the amino acids alanine, arginine, aspartic acid, cystine, glutamic acid, glycine, histidine, leucine-isoleucine, tyrosine, and valine. Specimens taken from the nonpolluted areas (Santa Catalina Island, San Clemente Island, and Anacapa Island) contained asparagine in addition to the above amino acids. The specimens taken from White's Point showed no asparagine, but did show a definite spot identified as aspartic acid. This acid was either absent or only very faintly discernible in the specimens from the nonpolluted areas. Phenylalanine and three unidentified spots were present in the specimens obtained from the White's Point area (Figs. 2, 3; Table 1).

All specimens of the crab, *Pachygrapsus crassipes,* contained the free amino acids alanine, arginine, aspartic acid, cystine, glutamic acid, glycine, histidine, leucine-isoleucine, lysine, methionine, proline, serine, threonine, tyrosine, and

valine. Specimens taken from Santa Catalina Island, Anacapa Island, and Morro Bay contained asparagine as well. Those from Santa Catalina and Anacapa islands contained an unidentified amino acid located to the right of arginine on the chromatographic pattern (Figs. 4, 5; Table 2).

DISCUSSION

Both *Haliotis cracherodii,* which occurs in one markedly polluted area, and *Pachygrapsus crassipes,* which was collected from a variety of polluted areas, have a free amino acid composition different from that of the same animals collected from nonpolluted areas. *Haliotis* from clean water gives a more consistent pattern than does *Pachygrapsus.* Both forms taken from polluted waters are marked by the absence of asparagine. This indicates that in some manner the metabolism dealing with this amino acid has been altered. In the case of *Haliotis* from White's Point, phenylalanine and three unidentified spots appeared, indicating a more extensive change in metabolic pattern. The change in the abalone is greater than that in the crab. This may be due either to a difference in response to polluted conditions because of the difference in the animals; or it may in some way be associated with the difference in length of time during which the animals are submerged and are subjected to the polluted conditions.

The factors of pollution common to the areas considered were a depletion of available oxygen and an increase in nutrients resulting

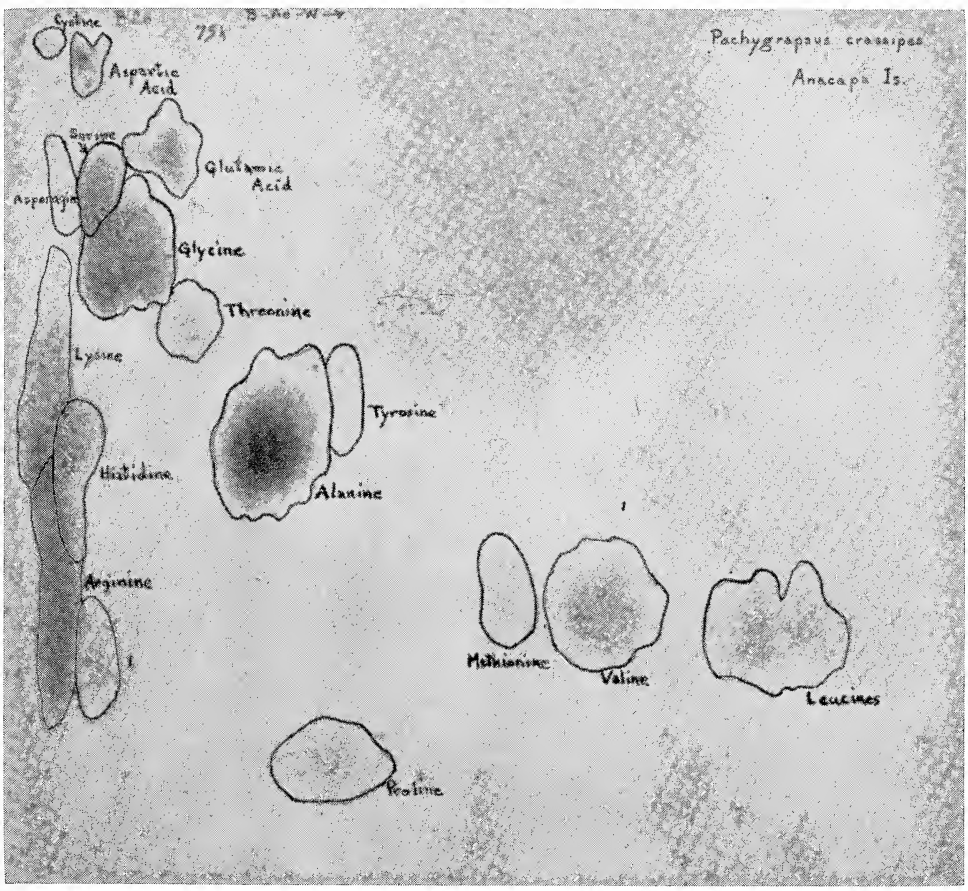

FIG. 4. Chromatogram of free amino acids of *Pachygrapsus crassipes* from Anacapa Island, a nonpolluted area.

TABLE 1

FREE AMINO ACIDS PRESENT IN SPECIMENS OF THE ABALONE, *Haliotis cracherodii*, FROM A POLLUTED AND THREE NONPOLLUTED AREAS

	ALANINE	ARGININE	ASPARTIC ACID	ASPARAGINE	CYSTINE	GLUTAMIC ACID	GLYCINE	HISTIDINE	LEUCINES	LYSINE	METHIONINE	PHENYLALANINE	PROLINE	SERINE	THREONINE	TYROSINE	VALINE	UNKNOWN #1	UNKNOWN #2	UNKNOWN #3
Santa Catalina Is.	×	×	×*	×	×	×	×	×	×	×	×		×	×	×	×	×			
Anacapa Is.	×	×		×	×	×	×	×	×	×	×		×	×	×	×	×			
San Clemente Is.	×	×		×	×	×	×	×	×	×	×		×	×	×	×	×			
White's Point	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×

* Very faint.

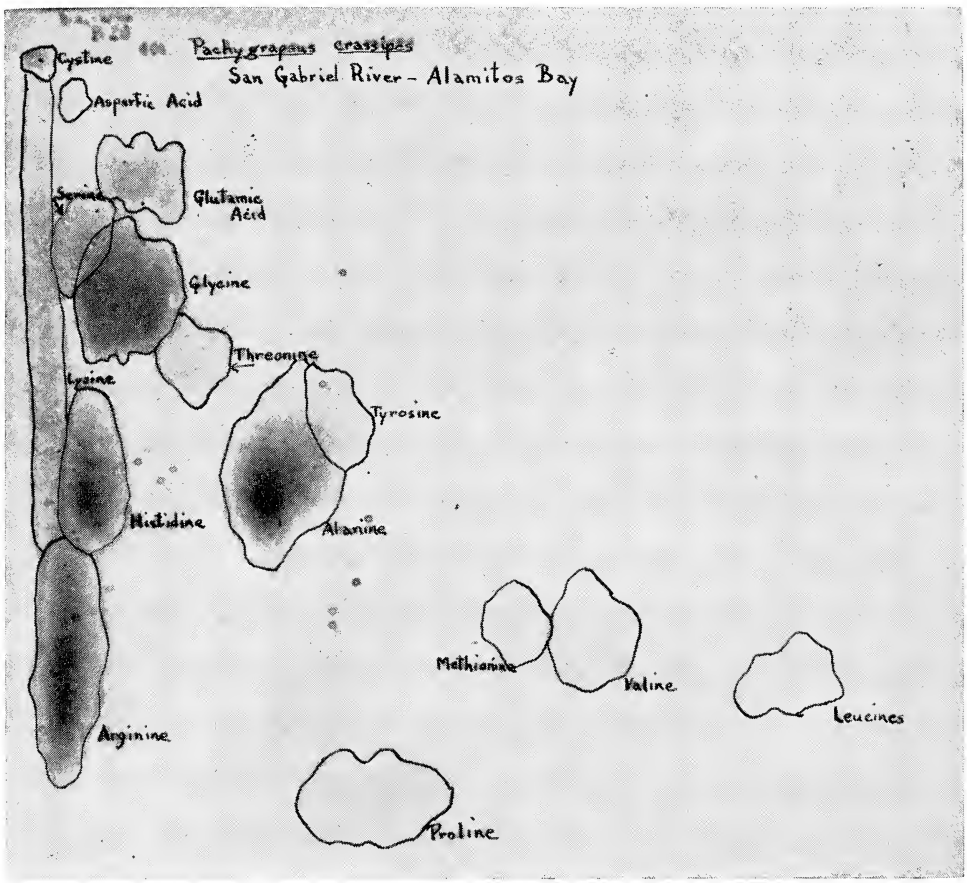

FIG. 5. Chromatogram of free amino acids of *Pachygrapsus crassipes* from the mouth of the San Gabriel River at Alamitos Bay, a polluted area.

TABLE 2

FREE AMINO ACIDS PRESENT IN SPECIMENS OF THE CRAB, *Pachygrapsus crassipes*, FROM FOUR NONPOLLUTED AND THREE POLLUTED AREAS

	ALANINE	ARGININE	ASPARTIC ACID	ASPARAGINE	CYSTINE	GLUTAMIC ACID	GLYCINE	HISTIDINE	LEUCINES	LYSINE	METHIONINE	PHENYLALANINE	PROLINE	SERINE	THREONINE	TYROSINE	VALINE	UNKNOWN #1
Santa Catalina Is.	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×
Anacapa Is.	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×		×
San Clemente Is.	×	×	×		×	×	×	×	×	×	×		×	×	×	×		
Morro Bay	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×		×
White's Point	×	×	×		×	×	×	×	×	×	×		×	×	×	×		
L. A. Harbor	×	×	×		×	×	×	×	×	×	×		×	×	×	×		
Alamitos Bay	×	×	×		×	×	×	×	×	×	×		×	×	×	×		

from sewage. Since the role of the free amino acids in the animal body is as yet not completely understood, it is not possible to state what physiological mechanisms have been altered by these environmental changes or whether one or both of the factors have operated to bring about the altered free amino acid metabolism. That a biochemical change as well as a morphological change has occurred is evident.

SUMMARY

1. Specimens of the abalone, *Haliotis cracherodii*, and the crab, *Pachygrapsus crassipes*, were collected from clean and polluted waters.

2. Chromatographic analysis of the free amino acids of these forms were made by two-dimensional paper chromatography.

3. Specimens from polluted areas were found to be lacking in asparagine. This amino acid was present in specimens from clean waters.

4. Phenylalanine and three unidentified amino acids, not found in *Haliotis cracherodii* from clean water, were present in this species taken from polluted water.

5. Polluted waters differed from nonpolluted waters in that they showed a depletion of available oxygen and an increase in nutrients.

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Studies in the Helminthocladiaceae (Rhodophyta): *Helminthocladia*[1]

MAXWELL S. DOTY[2] AND ISABELLA A. ABBOTT[3]

DURING RECENT WORK in the field with the algae of Hawaii several interesting red algae have been found. Two of these interesting algae which seem to be members of the Helminthocladiaceae are reported here, in the hope that more work with such algae will be encouraged.

The Helminthocladiaceae is accepted as being a family, the limits of which would include eight genera that are rather well known and perhaps three genera that are not well known, *Ardissonea, Dorella,* and *Endosira. Ardissonea* was described by J. Agardh (1899: 99) and is treated by Kylin (1956: 127), under the name of *Neoardissonia* Kylin, as a member of the Naccariaceae. *Dorella,* which may be a member of this family, has terminal cortical cells which are not enlarged. According to a personal communication from Dr. H. B. S. Womersley, the type of *Ardissonea* is a very finely branched alga and *Endosira* appears to be a juvenile of a different order. Kylin (1956: 557) suggests that *Endosira* may be related to *Nemastoma.* Consequently, we shall consider these genera no further in connection with the algae being described below.

Of the eight easily recognizable genera, only *Helminthocladia* possesses lateral carpogonial branches and zygotes (post-fertilization carpogonia) which divide transversely, longitudinally, or obliquely and give rise to a dense gonimoblast from both division products. In addition, in *Helminthocladia* the terminal vegetative cells in the cortex are strongly enlarged. Kylin (1956: 108) uses this latter as a key characteristic to separate this genus from *Helminthora.* There are other differences between the two genera: In *Helminthora,* for example, only the upper cell of a transversely dividing zygote gives rise to gonimoblast filaments. *Trichogloea* differs from *Helminthocladia* and from other well-known genera in having straight terminal, rather than curved lateral, carpogonial branches and in its calcification. *Dermonema* has long been a relatively unknown genus but is distinct in form, being erect cushions formed of noncalcified closely dichotomous branches, sometimes like *Chnoospora minima* in looks and habitat. Both *Dermonema* and *Cumagloia* (Gardner, 1917: 401) are distinct in having a diffuse gonimoblast ramifying among the cortical filaments near the zygote from which it originated as a few protuberances with no previous division of the zygote. The genus *Liagoropsis* of Yamada (1944) is like *Nemalion* (Desikachary, 1957*a*), having straight carpogonial branches, but differs in being calcified.

On the basis of various characteristics the algae to be described are judged to be distinct, new species of *Helminthocladia.* They represent the only records of this genus of the Rhodophyta for the Central Pacific Ocean.

Helminthocladia simplex sp. nov.

Figs. 1–18

DESCRIPTIO TYPI: Thalli irregulariter cylindrici, usque ad 9.5 cm. alt., acibus ramisque subsimplicibus saepissime 1 ad 1.5 mm. diam. Rami pauci, irregulariter dispositi. Thalli saepe simplices, qui saepe latiores quam thalli ramosi, raro, autem, plus quam 2 ad 4 mm. diam. Thalli simpliciores forma magis irregulares, clore magis obscuri, statura breviores saepe carpogoniales sunt. Thalli antheridiales ubique vel

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FIG. 1. The type of *Helminthocladia simplex,* a preparation on a herbarium sheet.

plerumque tenuiores, clore nitidiores, altiores, magis ramosi. Thalli textura ubique lubrici mollesque. Frondes multiaxiales, filamentis corticalibus nullo modo inter se adhaerentibus.

The holotype is a preparation of six thalli on one herbarium sheet deposited in the Bernice P. Bishop Museum in Honolulu, Hawaii. These specimens, along with a small *Liagora,* formed a turf on an almost horizontal rock surface just above extreme low tide line. The type material was collected by Jan Newhouse and Henry Kekoanui (M. Doty no. 12691) at Kahanahaiki, Waianae, Cahu, Hawaiian Islands (21° 32′ N., 158° 14′ W.), Jan. 2, 1954. Isotypes are being sent to the herbaria of the University of California, University of Michigan, Hopkins Marine Station of Stanford University, Cryptogamic Laboratory of the Paris Museum, University of Adelaide, South Australia, and Hokkaido University at Sapporo, Japan.

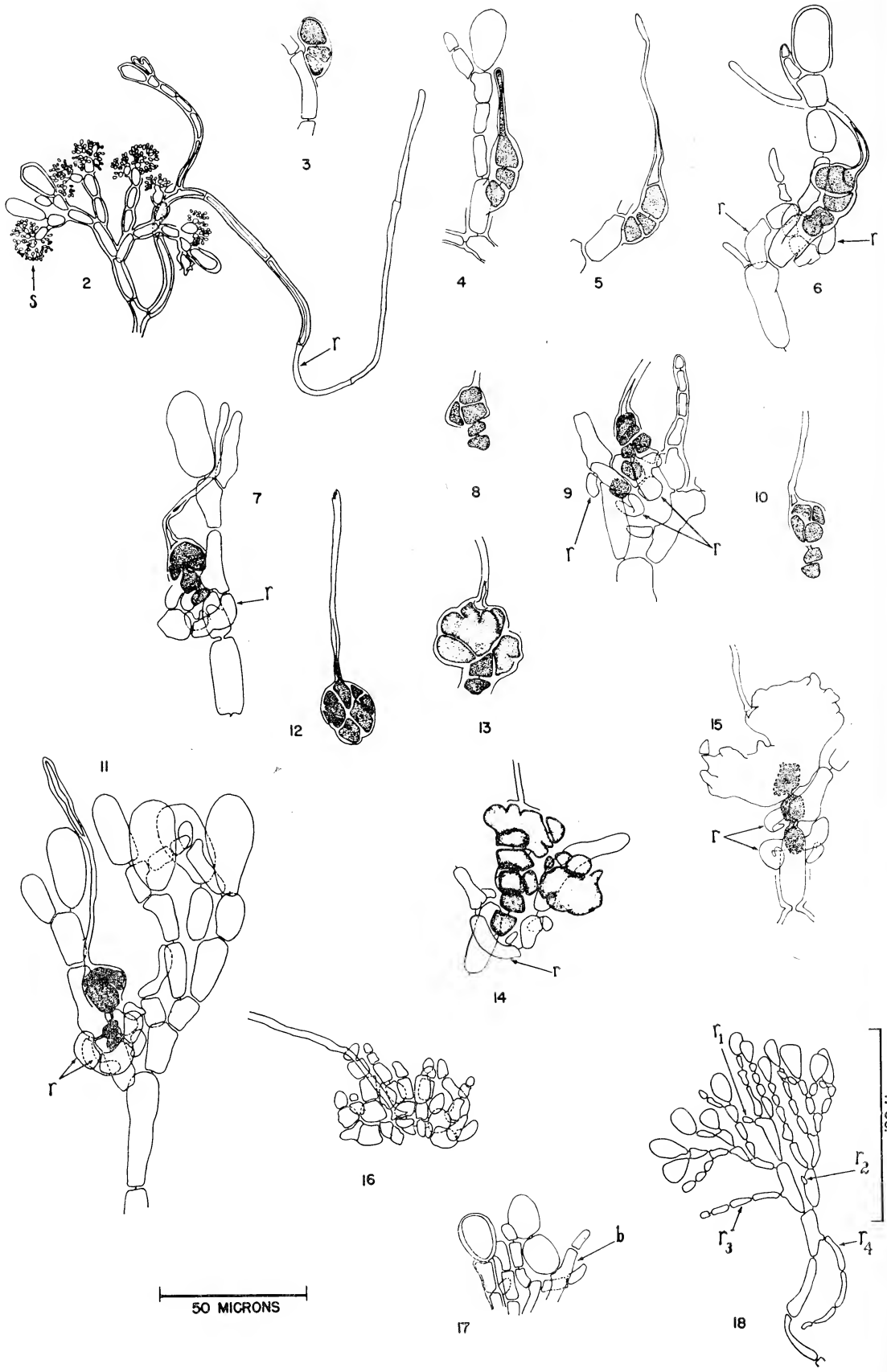
During some of the years since the original collection was made by Newhouse and Kekoanui, the type locality has been revisited. The sand shifts a great deal throughout the year at this site; sometimes the place is completely covered with sand. Until recently the alga had not been refound, though other members of the Helminthocladiaceae were often present in abundance. However, on Apr. 10, 1960, while Doty was accompanied by Newhouse and Ernani Menez, a dense stand of *H. simplex* (M. Doty no. 19135A, Menez no. 201) was found. The thalli were essentially of the same morphological form and were collected in the same place under the same conditions as the type. The living material was yellowish brown, with no taste or odor, and hard like a *Gracilaria* rather than soft like a *Trichogloea.* Perhaps a half liter of the species was obtained at this time. In time the algal population dwindled and the sand as well, until by May 8 there was very little of either on the site. The form of the *Helminthocladia simplex* present at this time was still the same as the other collections of this species, or perhaps a bit more eroded.

Thalli (Fig. 1) of irregularly cylindrical branches, up to 9.5 cm. tall, with most of the subsimple axes and branches 1–1.5 mm. in diameter. Branches irregular in arrangement and few. Thalli often simple, and these simple ones, while often of larger diameter than branched thalli, are rarely more than 2–4 mm. in diameter. Often the simpler thalli of more irregular form that are duller in color and shorter in stature are carpogonial. The antheridial thalli are generally more slender, more brightly colored, taller, and more branched. Texture rubbery and pliant throughout. The fronds are multiaxial and the cortical filaments do not adhere to each other in any way.

Our material is dioecious. No evidence of what might be a tetrasporangial generation was seen.

The male thalli produce spermatangia on terminal cortical cells among the vegetative filaments of the surface. The spermatangia are produced on cells (Fig. 2*s*) that are smaller than the adjacent vegetative cells and terminate in dichotomous rows of small cells. These small masses of cells do spread out under the cover glass on a microscope slide as do the terminal fans described for *Helminthocladia* by Martin (1939), but one suspects them of covering the surface area of the vegetative terminal cells they replace; i.e., occurring in round brushlike clusters rather than in two-dimensional fans. More than one spermatium may adhere to a trichogyne; those seen stuck to trichogynes were colorless.

The female apparatus develops laterally from the fourth or fifth cell (Figs. 3, 4, 5) below the enlarged terminal superficial cortical cell.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The terminal cell of the developing carpogonial branch is large at first (Fig. 3). Only three-celled carpogonial branches were seen (Fig. 15 notwithstanding). It often appeared (Figs. 5, 6, 7) that the trichogyne cytoplasm became separated from the zygote cytoplasm; this we accepted as evidence that fertilization had taken place. Few cases were studied where we were certain that only the first division of the zygote had taken place. A number of cases were seen where two (Figs. 6, 7, 8), three (Figs. 9, 10, 11), four, or five divisions (Fig. 12) had taken place. From these it was clear that division of the zygote is usually longitudinal or oblique, as in the case of *H. papenfussii* as illustrated by Martin (1939, figs. 17, 18).

Conspicuous post-fertilization changes were not apparent in the carpogonial branch cells other than in those derived from the carpogonium itself. No placental cell formation was seen. Pit connections within the carpogonial branch (Figs. 13, 14) and to the supporting cell and to the supra-supporting cell were not enlarged, or those between the carpogonial branch cells were only slightly enlarged. The hypogynous carpogonial branch cells in older stages (Figs. 13, 14) were "lighter staining" than during earlier stages. In the six or eight cases in older gonimoblasts studied in this regard (e.g., Fig. 15), the central complex of densely staining cells presumably derived from the carpogonial branch had only, at most, "broadened" pit connections. The contents of the supporting and supra-supporting cell were in some cases darkened and shrunken in diameter in this formalin-fixed material.

As in *H. papenfussii* (Martin, 1939), *Helminthora lindaueri* (Desikachary, 1955: 131), and in *Helminthocladia australis* (Desikachary, 1957*b*), encircling sterile rhizoid-like filaments (*r* in Figs. 6, 7, 9, 11, 14, 15) after fertilization grow especially around the hypogynous cells of the carpogonial branch. These were not seen to invade or surround older gonimoblasts of *H. simplex* when these were producing surfaceward-growing filaments. In fact they seemed largely to have disappeared or become lost in our preparations of older stages.

Gonimoblast initials appear from both primary division products of the zygote (Figs. 9–13). The cells of the young gonimoblast (Figs. 10–12) are at first in a dense regular mass which becomes lobed (Figs. 13, 14, 15) in time. In this respect our organism is like other *Helminthocladia* species and unlike other genera in the family.

From the dense indefinitely lobed central gonimoblast mass, sparsely branched rather parallel filaments (Fig. 16) grow towards the surface of the thallus. The gonimoblast filaments are usually unbranched for the terminal three cells. It may well be, though not followed out closely, that the terminal two cells tend to become carposporangia and the bottom (third one) gives rise (Fig. 17*b*) to a two-celled branch that in turn grows to look like the terminal two cells of the parent filament before they began enlarging into carposporangia. This same third cell may produce another branch. It is interesting to note this sympodial manner of growth here.

In some cases the third cell in the row becomes a carposporangium. In this respect the organism at hand approaches that condition illustrated by Kylin (1930, fig. 2D) for *H. calvadosii*. That is to say, there is nothing like the branching which Papenfuss (1946, fig. 25) illustrates for the homologous structures in *Trichogloea*.

DISCUSSION: The type, MD 12691, is distinguishable from the classical *Helminthocladia hudsoni* and *H. calvadosii* (accepted as the type species of the genus as circumscribed by Hamel,

FIGS. 2–18. Reproductory and anatomical features of *Helminthocladia simplex*. 2, Cellular details of a cortical filament system bearing spermatangia (*s*) apically and a rhizoid (*r*) from the assimilatory region. 3–5, Young carpogonial branches (stippled). 6–15, Stages in the development of the gonimoblast with its enveloping rhizoids. Individual cells are indicated by dark stippling; groups of cells are indicated by light stippling; enveloping rhizoids are indicated, and an assimilatory apical cortical cell. 16–17, Branching of the carpospore-producing filaments (*b*). 18, Cellular details of a cortical vegetative filament system showing the strongly dichotomous branching and, from the inner cortical regions, rhizoidal filaments (*r*).

1930), and from all other species known to the authors, in the reproductory structures described for these taxa and on the basis of their being more branched and larger in size. Specimens of *H. calvadosii* from France (University of California Herbarium no. 407401, identified by Kylin) measured 26–36 cm. tall, and in the parts examined lacked any trace of the sterile rhizoid-like filaments characteristic of our species and of *H. papenfussii.* Another specimen (University of California Herbarium no. 218320, labeled by Rosenvinge *H. purpurea*) was up to 60 cm. tall and likewise lacked the peculiar rhizoidal filaments around the hypogynous cells. This latter specimen was the most nearly simple in branching of any *Helminthocladia* examined by us aside from *H. simplex.* In regard to the enveloping rhizoidal filaments our organism is unlike *H. calvadosii* (Kylin, 1930), *H. hudsoni* (Feldmann, 1939) which have no such filaments, and *H. papenfussii* as described by Martin (1939) which has many such filaments. The most striking of these sterile filaments (Figs. 8, 9, 12, 14) arise from the cell above the supporting cell in the vegetative branch, but they are more complex than those Balakrishnan (1955) illustrates for *Liagora erecta.*

Martin (1939) ascribes both a fusion cell to *Helminthocladia papenfussii,* derived from the carpogonial branch, and a sterile envelope; these are illustrated in her figures 20 and 21. By the time a gonimoblast is this far developed in this Hawaiian species, there is no indication of either such a fusion cell or such an enveloping basket of sterile branches. The sterile rhizoidal branches develop in *H. simplex* as in some other *Helminthocladia* species where such may be found, primarily from the cell above the supporting cell in the vegetative branch, as Kylin (1938, fig. 1C) illustrates *H. papenfussii.* The first to appear tend strongly to encircle the young gonimoblast but they were not seen in older stages. Desikachary (1956, figs. 25, 29) illustrates a similar situation in *Helminthora lindaueri* from New Zealand.

The material reported and figured as *Helminthocladia australis* by Okamura (1916: 21) and by Segawa (1957: 58, fig. 254) seems to be similar to ours in habit, except for the larger size and greater degree of branching. However, Narita's (1918) figure of *H. yendoana,* which in that author's opinion includes *H. australis* of Okamura, does not resemble our alga at all. Furthermore, our examination of certain specimens (University of California Herbarium nos. 335335, a female thallus apparently identified by S. Narita; 279932, a female thallus identified by Y. Yamada; and 418162) shows the Japanese material to be different in other details as well. From the materials illustrated and discussed as *H. australis* by Desikachary (1957*b*), our material differs in being far simpler and smaller.

We refer here only briefly to the rhizoids (Fig. 18*r*) which develop from the lower cells of the cortical filament systems. Only rarely was there any indication of such a rhizoidal filament (see *r* in Figs. 2) in the outer part of the cortex that even recalls slightly the rhizoids peculiar to the next species. Figure 18 r_1–r_4 perhaps illustrates the ontogeny of this rhizoidal type. Note that the cortical cells (Fig. 18) are, in general, characteristic for *Helminthocladia.*

Helminthocladia rhizoidea sp. nov.
Figs. 19–24

DESCRIPTO TYPI: Thallus 9 cm. alt., valde mucosoideus, in partibus inferioribus radiatim ramosus; filamenta corticea usque ad 350 μ long., irregulariter dichotome tritomeve ramosa; cellulae apicales amplificatae, pyriformes, 13–26.5 μ lat., 45 μ long.; rhizoidea multa 4.8–7.2 μ lat., e filamentis corticeis exterioribus producta; gonimoblastus involucro filamentorum e cellulis minoribus quam cellulae corticis vegetativi consistantium, aliter, autem, filamentis assimilativis corticeis propinquis similium, circumdatus; filamenta involucri e cellulis vegetativis infra superque cellulam sustinentem producta.

The holotype is a preparation bearing the collection number MDoty 12860. The specimen was collected by Mr. Tetsuo Matsui at Lahaina (156° 41′ W., 20° 53′ N.), on the island of Maui, Hawaii, and it is deposited in the Bernice P. Bishop Museum, Honolulu, Hawaii.

Thallus (Fig. 19) of cylindrical branches, 9 cm. high, branching radial in the lower portions, the branches 4 mm. in diameter at their bases, gradually tapering to 1–2 mm. in diameter at the tips, strongly mucosoid. The main branches give rise laterally to shorter ones of irregular length between 1 and 3 cm. long. Basal disc 5 mm. in diameter.

Cortical filaments (Fig. 20) up to 350 μ in length, irregularly dichotomous or trichotomous, the lower cells ovoid to cylindrical, the terminal cells inflated and pyriform, 13–26.5 μ wide $\times$ 45 μ long. Short unbranched filaments, usually without the terminal pyriform cells, are commonly borne at the tops of the cortical filaments (Figs. 21*f*, 24*f*). Numerous, sometimes branched rhizoids 7.2–12 μ wide are produced from the medullary filaments. Rhizoids are also produced (Fig. 21*r*) by upper cells of the cortical filaments at first as protuberances 4.8–7.2 μ wide on the lower edge of the cells (Fig. 22*r*), then by elongation cutting off segments (Fig. 23*r*). They are linear, unbranched, and seem to connect neighboring assimilatory branches to each other, whereas those rhizoids produced nearer the axial strand add thickness to the axis. Occasional hairs (Fig. 21*b*) may be formed on the terminal cortical cells.

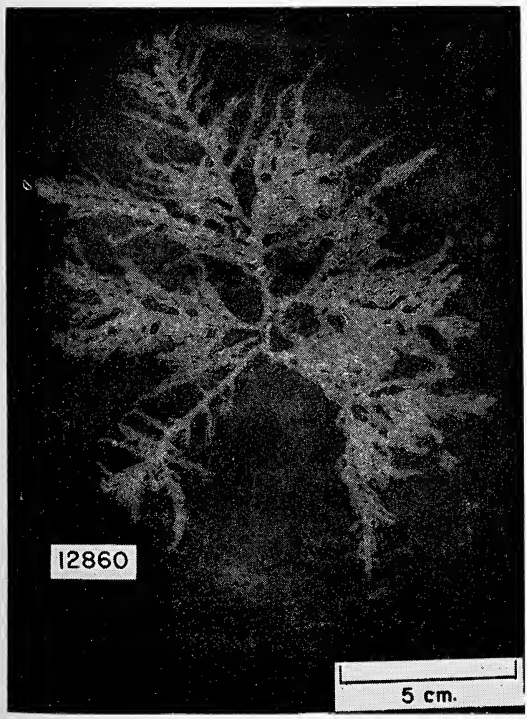
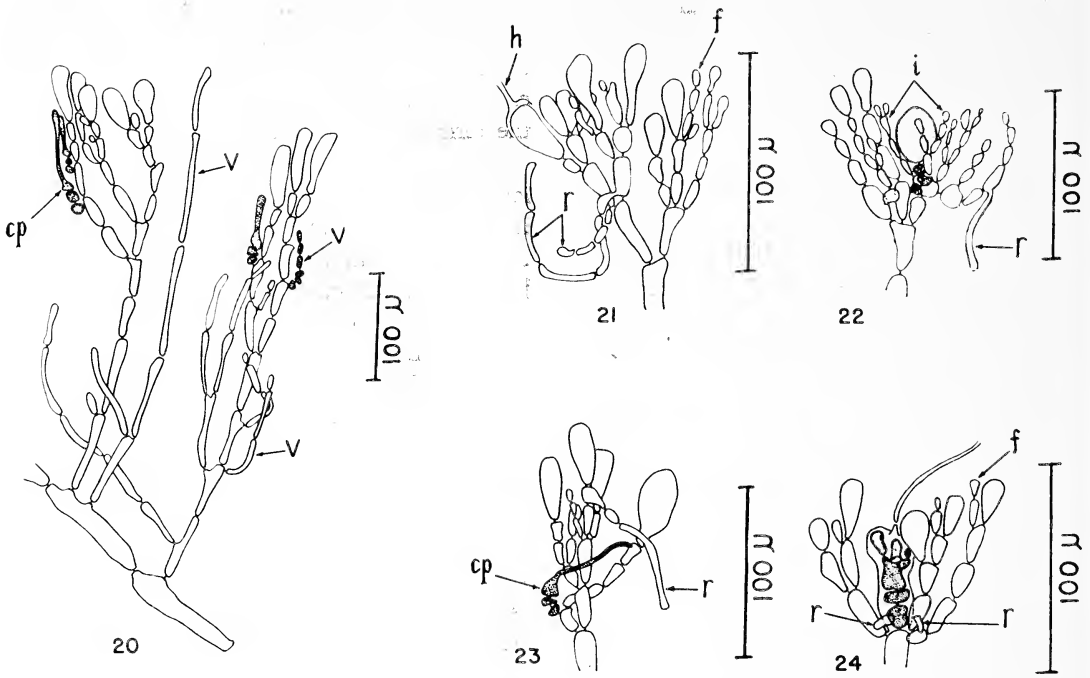


FIG. 19. The type of *Helminthocladia rhizoidea,* a single specimen preserved on a herbarium sheet.

Carpogonial branches 3-celled, curved, mostly lateral as specially formed branches (stippled in Figs. 20, 23) at or near a dichotomy, but occasionally taking the place of a vegetative branch at a dichotomy. If unfertilized, they may develop into cortical filaments (Fig. 20) that are of smaller diameter than the ordinary cortical filaments. The first division of the gonimoblast is longitudinal. Gonimoblast dense, regular in shape (Fig. 22), soon becoming an irregularly shaped dense mass of filaments with only the end cells producing carpospores.

A few sterile filaments are produced from the vegetative cells above the supporting cell (Fig. 24) or from those subtending the supporting cell (Fig. 22). They loosely bracket and overtop the gonimoblast (Fig. 22*i*), together with the vegetative filaments deflected by the growth of the cystocarp. No fusion cell is formed.

DISCUSSION: In its vegetative appearance (Fig. 19), *H. rhizoidea* is similar to certain other species of *Helminthocladia,* such as some forms of *H. australis* (Desikachary, 1957*b*, pl. 16, fig. 3). It is a strikingly different alga from *H. simplex,* described above (Fig. 1), which it does not resemble in either external or internal structure. However it is generally similar in external appearance to other well-described species of *Helminthocladia;* i.e., *H. calvadosii* (Kylin, 1930), *H. papenfussii* (Martin, 1939), and *H. australis* (Levring, 1953; Desikachary, 1957*b*). *H. rhizoidea* differs from these because of the production of decumbent rhizoids (*r* in Figs. 21–23) from the basal ends of the vegetative cells, which constitute the assimilatory filaments. While this fact in itself may not be of first importance, it does clearly separate this species from other species of *Helminthocladia.* Rhizoidal structures do appear nearer the medulla in *H. simplex* (Fig. 2) and in the *Helminthocladia* studied by Desikachary (1957*b*: 442, fig. 5), but these seem to have a different origin (see Fig. 18). It would seem that vegetative



FIGS. 20–24. Cellular reproductive and vegetative peculiarities of *Helminthocladia rhizoidea.* 20, A cortical heterofilamentous system, wherein some branches are of slender long cells (*v*) and some terminated by "normal" obpyriform cells, normal (e.g., *cp*) and seemingly abnormal carpogonial branches. 21, Cellular details of a cortical vegetative system illustrating a hair base (*h*), slender cortical filaments (*f*), and two of the rhizoids (*r*) which characteristically issue from the assimilatory region. 22, Origin of a rhizoid (*r*) from an assimilatory cortical filament, a well-developed gonimoblast (lightly stippled) with three hypogynous cells (darkly stippled) and several small-celled involucral filaments (*i*). 23, One of the rhizoids (*r*) peculiar to this species and well-formed carpogonial branch (*cp*). 24, A young gonimoblast with two one-celled encircling rhizoids (*r*) developed from supra-supporting cells, and a slender cortical filament (*f*).

characters of this kind are necessary aids to distinguishing the ever growing number of species in this genus.

The sterile filaments surrounding the cystocarp of *H. rhizoidea* (Fig. 22*i*) appear to resemble closely those in *H. papenfussii* as illustrated by Martin (1939), although the derivation of the sterile filaments may not be the same in both species. Martin states that the sterile filaments arise from the vegetative cell above the supporting cell in *H. papenfussii.* This is true also in *H. australis* (Desikachary, 1957*b*) where, however, they may also arise from the cell below the supporting cell. The derivation in *H. rhizoidea* also may be from above or below the supporting cell.

The possession of a loose basket of sterile filaments around the gonimoblast in *H. rhizoidea* seems to furnish a further characteristic for distinguishing this species from *H. simplex.* Only the initial few cells of the involucre are illustrated in Figures 22 and 24 for *H. rhizoidea,* while perhaps the ultimate in development of rhizoids is given in Figures 6, 7, 9, 11, 14, 15 for *H. simplex.*

Most species of *Helminthocladia* appear to have fairly regularly dichotomous assimilatory filaments; see the illustrations of *H. calvadosii* (Kylin, 1930), *H. hudsoni* (Feldmann, 1939), *H. australis* (Desikachary, 1957*b*), and those of *H. simplex,* especially Fig. 18 in this paper. In this respect *H. papenfussii* and the present

species are similar to each other in that the branches near the tops of the filaments are often trichotomous. The ultimate cells of the cortical filaments are more crowded, therefore, than those of most other species. Often in this genus where the cortical filaments are not dichotomous the production of carpogonial branches or rhizoidal branches (of the type illustrated in Fig. 18) seems to have been involved. Either normal carpogonial branches may have appeared (Figs. 20*cp*, 23*cp*), or abortive carpogonial branches may have become reorganized (Fig. 20*v*), possibly into vegetative branches.

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Studies on Pacific Ferns, Part III
The Lindsaeoid Ferns

G. BROWNLIE[1]

THE PRESENT STUDY arose from the fact that the genus *Lindsaea* has proved of particular interest from a cyto-taxonomic viewpoint, and, as the author hopes to deal with some of these ferns in the Pacific islands from that aspect, he took the opportunity of a period spent at the Herbarium of the Royal Botanic Gardens, Kew, to examine the collections located there. It quickly became evident that the species of lindsaeoid ferns, particularly those of New Caledonia, were poorly understood. There was not sufficient time and, in some cases, not sufficient material to completely clear up all doubtful aspects, but it is hoped that the present paper will go some distance towards clarifying the situation. To accomplish the task fully for the Pacific and neighbouring regions would require a work almost as large as the excellent revision of *Lindsaea* in the New World by Kramer (Acta Bot. Neerlandica 6, 97–290, 1957).

Taxonomically, the lindsaeoid ferns have proved a difficult group almost everywhere, and this is especially apparent in New Caledonia where both specific and generic distinctions are extremely doubtful. It is possible that they are a very old group whose close relationships are more apparent than real. This possibility has already been indicated by the limited cytological work published to date.

Acknowledgments. I wish to thank Mr. F. Ballard of the Royal Botanic Gardens, Kew, for his assistance, and I record my appreciation of the help given by the late Mr. A. H. G. Alston in connection with photographs of type material in Berlin herbaria. I also acknowledge the leave granted me by the Council of the University of Canterbury, during which this research was undertaken.

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Lindsaea dimorpha Bailey.

Lindsaea dimorpha Bailey. Handbook, Queensland Ferns 19, 1874.

L. anogrammoides C. Chr. Viert. Nat. Ges. Zurich 70, 223, 1925.

Christensen himself suggested that these two were closely related, and comparison of his type with Australian material shows that there is nothing to distinguish the New Caledonian specimen. It should consequently be recognized as *L. dimorpha.*

SPECIMENS EXAMINED: Franc 1308 in Herb. C. Chr. (Christensen's type; B. M.), Bailey unnumbered (Kew).

Lindsaea lapeyrousii (Hk.) Bak.

Davallia lapeyrousii Hk. 2nd. Cent. f. 56, 1861.

Lindsaea lapeyrousii (Hk.) Bak. Syn. Fil. 106, 1874.

L. kajewskii Copel. Journ. Arnold Arb. 12, 48, 1931.

In describing *L. kajewskii,* Copeland suggested that it was possibly related to *L. lapeyrousii,* but he apparently did not see Hooker's type specimen. Almost all recent collections of *L. lapeyrousii* have come from Fiji, where it is not uncommon, whereas Kajewski's specimen was obtained from Vanikoro Island in the Santa Cruz group. Hooker's type has, however, the locality given as "Vanicolla Island," which appears to be nothing more than an older rendering of Vanikoro, so that both specimens originated from the same island. The lack of subsequent material can be due only to the infrequency of collecting there. Copeland's paper gives the collection number as Kajewski 523, whereas a Kajewski specimen from Vanikoro at Kew inscribed "*Lindsaea kajewskii* n. sp." is numbered 533. The director of the Arnold Arboretum has

kindly informed me that the specimen there, used by Copeland, is also 533, so that the number quoted in the published description is obviously an error.

SPECIMENS EXAMINED: From Vanikoro—Herb. Hk. without collector (Kew), Kajewski 533 (Kew).

Lindsaea nervosa Mett.

Lindsaea nervosa Mett. Ann. Sc. Nat. IV, 15, 62, 1861.

A comparison of New Caledonian material collected by Vieillard showed a discrepancy for a particular collection number. Mettenius gave the type specimen of his *L. nervosa* as Vieillard 1540, locality Mons Dore, which is presumably Mont Dore, whereas sheets at both Kew and the British Museum (Natural History) bearing that number were specimens of *Schizoloma prolongata,* collected at Wagap. The Mettenius type obtained from Paris proved to be exactly what other collectors had understood as *Lindsaea nervosa,* and did indeed have the number and locality given in the published description. It appears that two widely separated collections have received the same number. Accidents such as this have contributed in some measure to the confusion surrounding many species from New Caledonia.

Schizoloma prolongata (Fourn.) Brownlie, comb. nov.

Lindsaea prolongata Fourn. Ann. Sc. Nat. V, 18, 334, 1873.

L. cheiroides Fourn. Ann. Sc. Nat. V, 18, 334, 1873.

Comparison of the collections at Kew and the British Museum with one of Fournier's type specimens of *L. cheiroides* (Balansa, 1602) leads to the conclusion that these are all better regarded as examples of one variable species. The name *L. cheiroides* has been applied to a form with a markedly elongated apical portion of the frond and with the lobing of the sterile pinnules accentuated to serrations. *L. prolongata* as understood by Fournier and others has pinnules with rounded lobes, and the terminal division of the frond is not elongated. However, variation from rounding to serration of the pinnules may be observed even within a single specimen, and since the other characters appear to be identical there are no grounds for retaining them as separate species. It appears possible that these may also grade into *Schizoloma heterophyllum* var. *majus* (Christensen, Viert. Nat. Ges. Zurich 77, 8, 1932). On the basis of Holttum's understanding of the lindsaeoid genera (Flora of Malaya 2, 320, 1954), it should be placed in the genus *Schizoloma.*

SPECIMENS EXAMINED: MacGillivray 27 (B.M.), unnumbered (Kew), Herb. Macleay unnumbered (Kew), Vieillard 1540 (Kew and B.M.), Balansa 1602 (Paris), le Rat 943 and 965 (Kew), Franc 11 and 33 (B.M.) and 365 and 679 (Kew), Pancher unnumbered (B.M.), Compton 541 (B.M.), Buccholz 1260 (Kew).

Tapeinidium flavicans (Mett. ex Fourn.) Hier. Hedwigia 62, 13, 1920.

Lindsaea flavicans Mett. Mem. Soc. Sc. Nat. Cherb. 10, 317, 1867 (nomen); Fourn. Ann. Sc. Nat. V, 18, 334, 1873.

L. tenuifolia Mett. Ann. Sc. Nat. IV, 15, 64, 1861 (non Bl.).

L. balansae Fourn. Ann. Sc. Nat. V, 18, 335, 1873.

L. campylophylla Fourn. Ann. Sc. Nat. V, 18, 335, 1873.

Davallia lenormandi Bak. Syn. Fil. 471, 1874.

Odontosoria lenormandi (Bak.) C. Chr. Ind. Fil. 465, 1906.

This is another example of several graded forms having been described under different names. Baker's *Davallia lenormandi* is represented at Kew by Vieillard 1548 and 1549 and by Pancher unnumbered. These specimens show considerable variation in degree of fineness and dissection of the fronds, but all are recognized as the one species. A single sheet, MacGillivray 14, which is given by Fournier as an example of *Lindsaea flavicans,* is identical with the most dissected form of Baker's species. Balansa 1652, the type of *L. balansae,* is another very dissected form with somewhat more open habit but is otherwise indistinguishable. This possibility had already been suggested by Christensen (Viert.

Nat. Ges. Zurich 74, 60, 1929). Similarly Balansa 854, the type specimen of *L. campylophylla,* differs only in the slightly longer tertiary and quaternary segments. All should be united under the one species *Tapeinidium flavicans.* It seems possible that the related species *T. moorei* (Hk.) Hier. may even represent a decidedly coarse form of the same species, but enough comparative material was not available to decide this with certainty.

Christensen identified *Lindsaea tenuifolia* of Mettenius with *Sphenomeris chusana* (L.) Copel., which does occur in New Caledonia, but Vieillard 1548 and 1549, which Mettenius gives as his species, represent Baker's *Davallia lenormandi.* Since that has been reduced to *Tapeinidium flavicans, Lindsaea tenuifolia* Mett. must also be a synonym of that species.

SPECIMENS EXAMINED: MacGillivray 14 (B.M.), unnumbered (Kew), Vieillard 1548 and 1549 (Kew), Pancher unnumbered (Kew), Balansa 854 and 1652 (Paris), Schlechter 15046 (Kew and B.M.).

Sphenomeris chusana (L.) Copel.

Lindsaea retusa Mett. Ann. Sc. Nat. IV, 15, 63, 1861.

This appears to have been an incorrect identification, because the plant is not the same as *L. retusa* of Indonesia. Mettenius gives his specimen as Vieillard 1547, but an examination of the sheet used by him shows this to be a large example of the widespread *Sphenomeris chusana* which has been collected frequently in New Caledonia.

SPECIMEN EXAMINED: Vieillard 1547 (Paris).

SUMMARY

Five species of the genus *Lindsaea* from New Caledonia and one from Vanikoro Island are reduced to synonyms either of other species of *Lindsaea* or of species of related lindsaeoid ferns. One species has also been transferred from *Lindsaea* to *Schizoloma.* A number of confusing aspects of collections of *Lindsaea* from New Caledonia have been clarified.

Further collections from New Caledonia appear to be necessary to elucidate the relationships among the three species *L. macgillivrayi* Carr., *L. nervosa* Mett., and *L. neocaledonica* Compton, and to define the specific limits within the genus *Schizoloma.*

Two New Chaetognaths from the Pacific

ANGELES ALVARIÑO[1]

THE PRESENT PAPER deals with two species of chaetognaths observed when working on the distribution of this group in California waters, and on their relation to the hydrographic conditions of the area. The material was collected by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) off the coast of California, a project sponsored by the Marine Research Committee of the State of California.

Acknowledgments. I wish to thank Dr. M. W. Johnson, who has given me a great deal of valuable advice and many helpful suggestions during the preparation of this paper, and who has also corrected the typescript and provided space for me in the Marine Invertebrates Department to carry out my work on zooplankton. I am also greatly indebted to Dr. R. Revelle and Professor J. D. Issacs for their interest in providing an opportunity for me to work and continue my research at this Institution. I also offer my sincere thanks to Gail Holden Theilacker for doing the drawings contained in this paper.

[1] Scripps Institution of Oceanography, University of California, La Jolla, California. Manuscript received July 22, 1959.

Sagitta bierii n. sp.

The body is rigid and slender, retaining its cylindrical shape. It is transparent, so that the ovaries are easily seen and the gut appears as a dark straight line along the body. The small head is attached to a long narrow neck which gradually broadens out into the body, which is widest at the level of the ovaries. The shape

TABLE 1

MEASUREMENTS OF *Sagitta bierii* n. sp.

NUMBER OF SPECIMENS	TOTAL LENGTH, MM.	TAIL LENGTH, MM.		OVARY LENGTH, MM.		HOOKS		ANTERIOR TEETH		POSTERIOR TEETH	
		Median	Range	Median	Range	Mode	Range	Mode	Range	Mode	Range
2	17.0	3.5		3.5	(3.0–4.0)	6		6			(14–16)
6	16.0	3.2	(3.0–3.5)	2.5	(1.3–4.5)	6		6	(6–8)	14	(12–16)
18	15.0	3.08	(3.0–3.5)	2.4	(0.5–4.5)	6	(5–6)	6	(6–7)	14	(12–18)
7	14.5	3.01	(3.0–3.5)	2.6	(1.0–4.0)	6	(5–6)	6	(6–7)	14	(12–16)
30	14.0	3.0	(3.0–3.2)	2.37	(1.0–4.0)	6	(6–7)	6	(6–8)	14	(12–18)
33	13.5	2.9	(2.8–3.5)	1.9	(1.0–4.0)	6	(6–7)	6	(6–8)	14	(12–18)
42	13.0	2.8	(2.5–3.5)	2.0	(1.0–4.0)	6	(6–7)	6	(6–8)	14	(12–18)
29	12.5	2.7	(2.5–3.0)	1.3	(0.8–3.0)	6	(6–7)	6	(6–7)	14	(12–18)
40	12.0	2.78	(2.2–3.0)	1.7	(0.5–2.4)	6	(6–7)	6	(5–8)	12	(12–18)
26	11.5	2.6	(2.5–2.9)	0.9	(0.2–2.0)	6	(6–7)	6	(5–6)	12	(12–14)
29	11.0	2.6	(2.2–2.8)	0.7	(0.0–2.0)	6	(6–7)	6	(4–7)	12	(10–16)
23	10.5	2.3	(2.2–2.6)	0.3	(0.0–1.0)	6	(6–7)	6	(4–6)	12	(10–14)
20	10.0	2.29	(2.0–2.5)	0.14	(0.0–1.2)	6	(6–7)	4	(4–6)	10	(10–12)
14	9.5	2.1	(2.0–2.5)	0.16	(0.0–0.5)	6	(6–7)	4	(3–6)	10	(10–13)
18	9.0	2.1	(2.0–2.4)			6	(6–7)	4	(3–6)	10	(8–12)
10	8.5	2.08	(2.0–2.2)			6	(6–7)	4	(3–5)	10	(8–12)
11	8.0	2.0	(1.9–2.2)			6	(6–7)	4	(3–4)	10	(10–14)
7	7.5	1.77	(1.7–2.0)			6	(6–7)	4	(3–5)	10	(8–10)
6	7.0	1.75	(1.6–2.0)			6	(6–7)	3	(3–4)	10	(8–10)
5	6.5	1.72	(1.6–1.8)			6	(6–)	3	(3–4)	8	(8–10)
3	6.0	1.6	(1.5–1.7)			6	(6–7)	3	(3–4)	8	(2–10)
1	5.0	1.8				7		3		6	

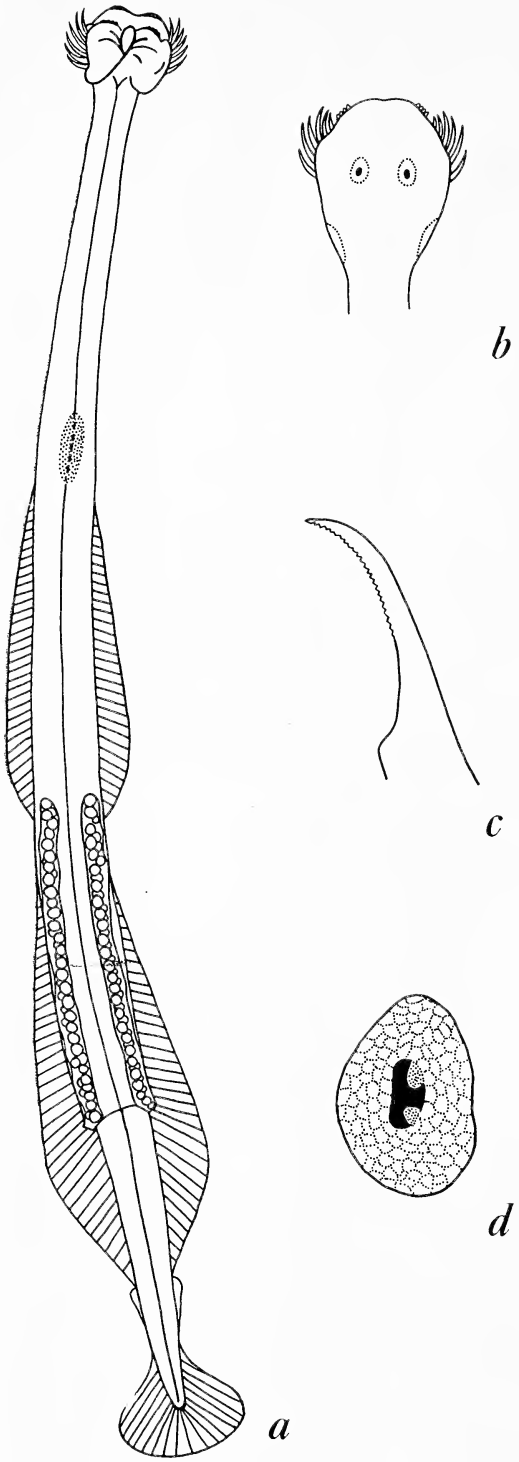

FIG. 1. *Sagitta bierii. a,* Ventral view; *b,* dorsal view; *c,* hook; *d,* left eye.

of the body resembles *Sagitta decipiens* Fowler. That species, however, is more transparent and flaccid and differs in the position of the fins and in having hooks without serrations.

The anterior fins begin at the level of the posterior end of the ventral ganglion. They broaden at their posterior end and are without a rayless zone.

The posterior fins begin at a short distance from the posterior end of the anterior fins and end at the level of the seminal vesicles. They are somewhat roundly triangular in shape and about the same or slightly longer than the anterior fins. They are broadest behind the tail septum, but their greatest length lies in the trunk region. They do not have a rayless zone (Fig. 1*a*).

The head is small, slightly elongated in the longitudinal axis, and thus differs from *S. decipiens* Fowler, which has a larger head (Fig. 1*b*).

The hooks have strong serrations as in other species of the "*serratodentata* group." The serrations are very conspicuous with low magnifications (Fig. 1*c*).

The eye pigment forms a kidney-shaped body which in the long axis is one-half the width of the eye, with the longitudinal diameter longer than the transverse (Fig. 1*d*).

The collarette is small.

The seminal vesicles are triangular to pear shape and not very conspicuous. The species is not as protandric as most chaetognaths (Figs. 2*a, b,* 3*a*). In about 60,000 specimens studied, less than a dozen appeared with the seminal vesicles well developed or undamaged. The seminal vesicles do not touch the tail fin.

The ovaries are long, fine tubes; when mature they reach to the posterior end or the middle of the anterior fins. The right ovary is usually shorter. Viewed laterally, the alternated position of the ovulae is clearly seen (Fig. 3*b*).

The number of ovulae in mature specimens is from 30 to 48.

LENGTH: In a well-mixed population the most abundant size is 12–14 mm. In April, 1958, from Monterey northwards, the prevailing size was from 14 mm. to 17 mm. The northern specimens all had stronger bodies and those from 13 to 15 mm. in length were mostly immature (Fig. 4).

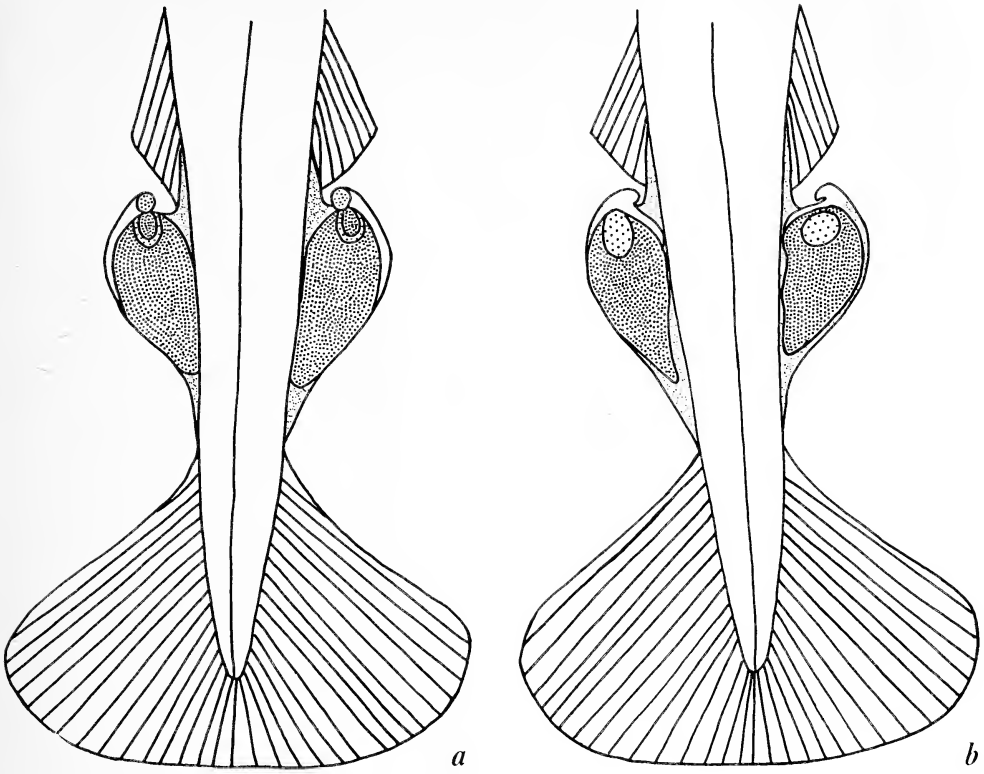

FIG. 2. *Sagitta bierii. a,* Seminal vesicles, dorsal view; *b,* ventral view.

Immature specimens 16 mm. long with almost no trace of ovaries were found. Others were observed with ovaries 1.0–1.5 mm. in length. A summary of measurements is given in Table 1.

DISTRIBUTION: The species was recorded by R. Bieri (1957) in Peruvian waters, from collections of the Transpacific Expedition, and from Cape Blanco to Punta Eugenia (Baja California) (Bieri, 1959). It was found in the CalCOFI collections of April, 1958, from Cape Mendocino, the northern limit of the sampling, down to the southern part of Baja California, as well as in the plankton samples from Peruvian waters taken by the Consejo de Investigaciones Hidrográficas del Perú in February and April, 1958.

S. bierii is found mainly from 100 to 580 mi. offshore, and hence it is not coastal in habitat.

RELATIONSHIPS: The shape of the seminal vesicles in the various forms of the "*serratodentata* group" is discussed by Ritter-Zahony, 1911*b*; Tokioka, 1939, 1940; Thomson, 1947; and Furnestin, 1953, 1957. In the present report, based on material from the Pacific and the Atlantic, the differences observed are given in Figures 5, 6, and 7 to compare with Figures 2 and 3.

S. serratodentata tasmanica reported by Tokioka (1959) apparently is *S. bierii* n. sp. for the following reasons:

He says that *S. selkirki* Fagetti, from Chilean waters "resembles most closely *tasmanica* in the appearance of the seminal vesicles." This is true and the species are certainly synonymous. The characteristic of the seminal vesicles as well as the other specific characters are identical for both. The anterior part of the seminal vesicles in both *S. serratodentata tasmanica* Thomson

and *S. selkirki* Fagetti have numerous short, soft protuberances (Fig. 6). This being true, *S. serratodentata tasmanica* cannot possibly be the species Tokioka describes (1959). The seminal vesicles which Tokioka (1959, fig. 7, p. 368) illustrated and described as belonging to *S. serratodentata tasmanica* Thomson, differ from the descriptions and figures of the seminal vesicles for this species as given by Thomson (1947) and Furnestin (1957), and for *S. selkirki* by Fagetti (1958). *S. bierii* n. sp., recorded

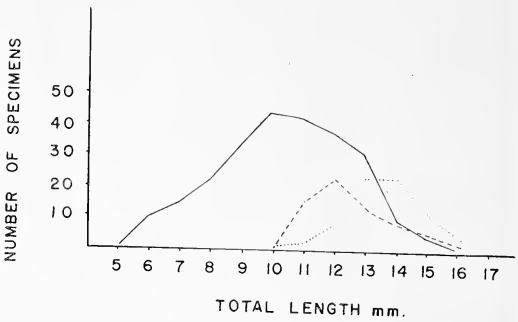

FIG. 4. *Sagitta bierii.* Distribution of size in relation to the sexual stages, April 1958. Stage I, ——; Stage II, -----; Stage III, ...

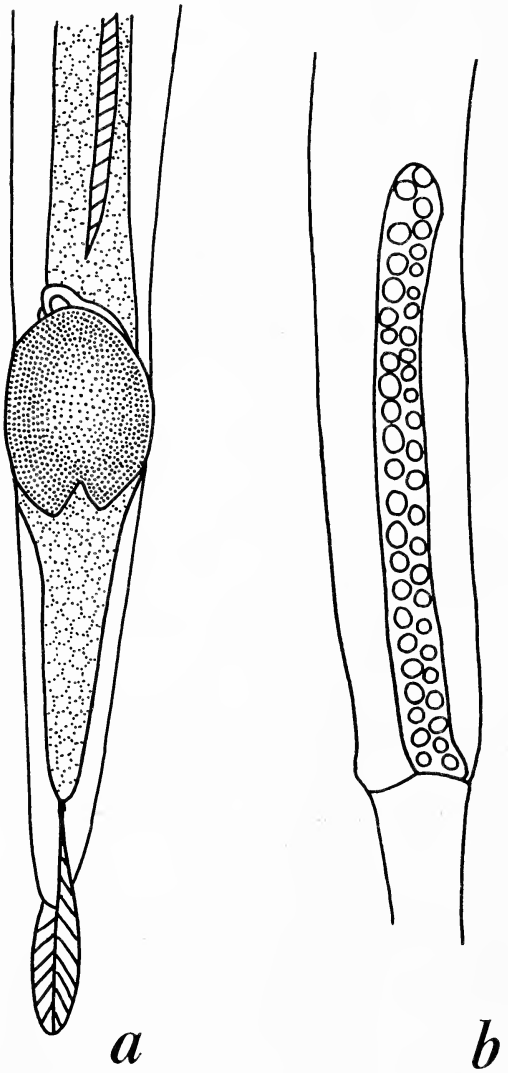

FIG. 3. *Sagitta bierii. a,* Seminal vesicles, lateral view; *b,* ovary, lateral view.

from the same area where Tokioka (1959) reports *S. serratodentata tasmanica,* has seminal vesicles with one prominence at the anterior end (Fig. 2*a, b*) as figured by Tokioka for *S. serratodentata tasmanica.*

Tokioka's (1959, fig. 12, p. 372) figure of the left seminal vesicle for ? *S. serratodentata atlantica* does not agree with his own description of the seminal vesicles for this species (Tokioka, 1940, p. 373 and fig. 7d, p. 374) nor with that given by Furnestin (1957, fig. 53, p. 150). The seminal vesicle which Tokioka (1959) describes as belonging to ? *S. serratodentata atlantica* agrees with his drawing for *S. serratodentata tasmanica* in the same paper.

In revising the chaetognaths of the "*serratodentata* group" from both the Atlantic and Pacific, it was easy to separate specimens belonging to the different species. Since the characteristics for each species appear constant with no characteristics in common among the different species except for the serrations on the hooks, each one can be considered to rank as a species. The fact that each one of these species typifies different masses of water offers additional evidence for considering each one a good species. A revision of the name of each species appears at the top of each column in Table 2.

Named after Dr. Robert Bieri, who recorded it in his work as *Sagitta* sp. in the "*serratodentata* group."

HOLOTYPE: USNM no. 29919.

PARATYPES: USNM no. 29920.

TABLE 2

PRINCIPAL DIFFERENTIAL CHARACTERISTICS OF THE "*Serratodentata* GROUP"

	S. serratodentata Krohn 1853 *S. serratodentata atlantica* Tokioka 1940, Thomson 1947, Furnestin 1953, 1957	*S. pseudoserratodentata* Tokioka 1939	*S. pacifica* Tokioka *S. serratodentata pacifica,* Tokioka 1940, Thomson 1947, Furnestin 1953, 1957	*S. tasmanica* Thomson *S. serratodentata tasmanica* Thomson 1947, Furnestin 1953, 1957 *S. selkirki* Fagetti 1958	*S. bierii* n. sp.
Total length, mature, mm.	10–13	7–10	12–14	15–20	14–17
% tail	23–26	26–29	23–26	22–26	20.5–23.3
Body shape	Same width from head to tail septum.	Same.	Same.	Same.	Neck region long, thin. Body widest at ovary region.
Collarette	Well apparent.	Smaller than in *S. serratodentata.*	As in *S. pseudoserratodentata.*	As in *S. serratodentata.*	Very small, if present.
Posterior fins	Long, rounded. About same length on tail as on trunk. At level of tail, septum begins rayless zone which extends over anterior part of fin.	Long, rounded, more on tail than trunk. Very close to posterior fins. Internal portion of fins on trunk is rayless.	As in *S. pseudoserratodentata.* Very close to anterior fins. No rayless zone.	Continuous with anterior fins by extremely narrow connexion, not visible with low power 10× and in badly preserved specimens. More on tail than trunk. Rayless zone begins at level of first third of tail extending over anterior part of fin as in *S. serratodentata.*	Triangular, rounded, more on trunk than tail. No rayless zone.
Seminal vesicles	Separated from tail fin, close to posterior fins. Two prominences at anterior lateral corner. Thickening of collarette tissue in front of anterior end. Markedly protandric.	Close to posterior end of posterior fins and at longer distance from tail fin. One prominence at lateral anterior corner and small teeth at anterior end. Protandric.	Oval with thickening frothy tissue. 5–10 chitinous teeth at anterior end. Protandric.	Close to posterior fins, separated from tail fin. Numerous short protuberances at anterior end. Notable thickening in front and behind vesicle. Markedly protandric.	Pear shape. One prominence and no soft protuberances as in *S. tasmanica.*
Ovaries	Long tubes extending to anterior end of anterior fins. Ovulae small and in one row.	Fine tubes extending to anterior end of ventral ganglion. Ovulae large for size of specimens, arranged in one row.	Very fine tubes, extending up to neck. Ovulae in one row.	Long tubes extending to ventral ganglion. Ovulae in two rows.	Fine tubes extending to posterior end of anterior fins. Ovulae in two rows.

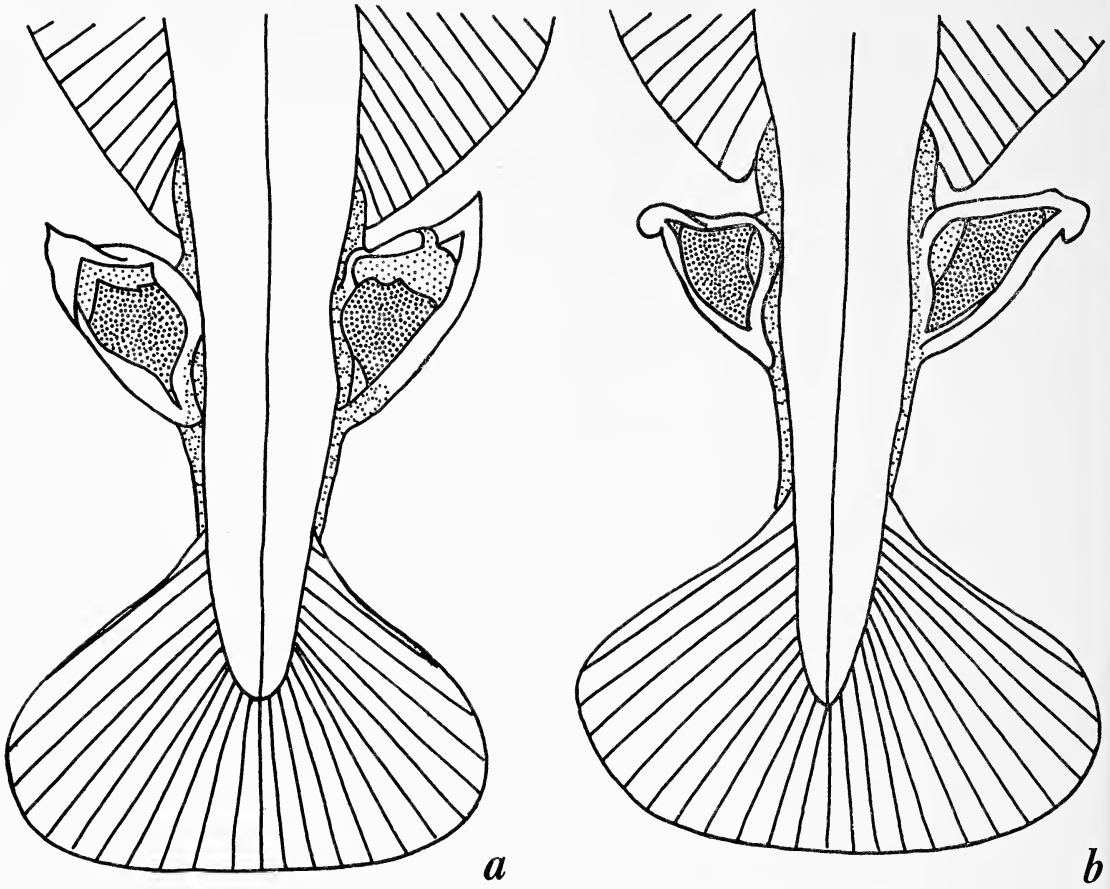

FIG. 5. *Sagitta pseudoserratodentata* Tokioka, seminal vesicles, two phases observed.

Sagitta euneritica n. sp.

The body is very translucent, almost transparent as in *Sagitta setosa* Müller; however, the larger specimens which mature at a size over 13 mm. in length appear less transparent. The body is uniform in width, narrowing at the head and at the tail ends. The rather poorly marked neck region is filled by a collarette. Viewed dorsoventrally on a dark background, the gut appears as a narrow white line extending from the head down to the body as in *S. setosa.*

The anterior fins do not reach the ventral ganglion. They are wider at the posterior end and have no rayless zone.

The posterior fins lie more on the trunk than on the tail. They are longer than the anterior fins, broadest behind the level of the tail septum, and they end touching the seminal vesicles. They are without a rayless zone (Fig. 8*a*).

The head is somewhat square and regular in size.

The eye pigment is gathered into a rather perfect square with several clear spots which differ in position and shape from those of *S. setosa* and *S. euxina* Moltschanoff (Furnestin, 1958) (Fig. 8*c*, *d*).

The collarette is well developed with the characteristic structure of round cells in a network.

The sensorial cells are spread all over the body as they are in *S. setosa* and *S. friderici* Ritter-Zahony.

The seminal vesicles are in contact with the tail fin and with the posterior fins. They are not very prominent, being small and similar to

TABLE 3

MEASUREMENTS OF *Sagitta euneritica* n. sp.

NUMBER OF SPECIMENS	TOTAL LENGTH, MM.	TAIL LENGTH, MM.		OVARY LENGTH, MM.		HOOKS		ANTERIOR TEETH		POSTERIOR TEETH	
		Median	Range	Median	Range	Mode	Range	Mode	Range	Mode	Range
2	15.5	3.2	(3.0–3.4)	2.0	(2.0–2.0)	7–9		6–8		14–16	
7	15.0	3.2	(3.0–3.4)	1.6	(1.0–2.2)	8	(8–9)	6	(5–7)	14	(10–16)
7	14.5	3.1	(3.0–3.2)	1.3	(1.0–2.5)	8	(7–9)	6	(5–7)	12	(12–16)
30	14.0	2.9	(2.5–3.2)	1.59	(1.0–2.3)	8	(7–8)	6	(6–7)	14	(10–16)
34	13.5	2.8	(2.5–3.0)	1.52	(1.0–2.0)	8	(7–9)	6	(4–7)	12	(10–16)
54	13.0	2.58	(2.5–3.2)	1.5	(0.4–3.0)	8	(7–9)	6	(5–7)	12	(10–16)
16	12.5	2.6	(2.5–3.0)	1.2	(0.6–2.6)	8	(7–8)	6	(5–6)	12	(10–12)
44	12.0	2.7	(2.3–3.0)	1.2	(0.0–2.5)	8	(7–9)	6	(4–7)	12	(10–16)
16	11.5	2.6	(2.3–2.6)	0.8	(0.3–2.0)	8	(7–8)	6	(4–7)	12	(10–12)
15	11.0	2.2	(2.0–2.6)	0.66	(0.3–1.3)	8	(7–8)	6	(4–6)	10	(10–14)
10	10.5	2.05	(2.0–2.3)	0.56	(0.3–1.0)	8	(6–8)	6	(4–6)	10	(10–12)
9	10.0	2.0	(2.0–2.2)	0.54	(0.3–1.1)	8	(7–8)	6	(4–6)	10	(10–12)
7	9.5	1.9	(1.8–2.0)	0.41	(0.2–0.7)	8	(7–8)	6	(3–6)	10	(8–12)
6	9.0	1.8	(1.6–2.0)	0.25	(0.1–0.4)	8	(7–8)	4	(2–6)	8	(6–12)
7	8.5	1.8	(1.5–2.0)	0.2	(0.1–0.3)	8	(7–8)	4	(3–6)	8	(8–10)
6	8.0	1.7	(1.5–2.0)	0.18	(0.1–0.3)	8	(7–8)	3	(3–6)	8	(8–10)
6	7.5	1.7	(1.5–2.0)	0.1	(0.1–0.2)	8	(7–8)	3	(3–5)	8	(8–10)
4	7.0	1.6	(1.4–1.9)	0.1	(0.1–0.2)	8	(7–8)	3	(3–5)	8	(8–10)
5	6.5	1.4	(1.3–1.5)	0.1	(0.1–0.2)	8	(7–8)	3	(2–4)	8	(6– 8)
5	6.0	1.4	(1.3–1.5)	0.1		8	(7–8)	3	(2–4)	7	(7– 8)
2	5.0	1.2	(1.2–1.3)			7			(2–3)		(6– 8)
1	4.5	1.2				8		2		6	
1	4.0	0.9				7		2		6	

TABLE 4

PRINCIPAL DIFFERENTIAL CHARACTERISTICS OF FORMS CLOSELY RELATED TO *Sagitta euneritica* n. sp.

	S. setosa Müller	*S. friderici* Ritter-Zahony	*S. euneritica* n. sp.
Total length, mm., mature	10–14	10–15	10.5–15.5
% tail	16–21.7	22.6–27	19–22
Anterior fins	Begin somewhat behind ventral ganglion.	Begin at posterior end of ventral ganglion.	Begin a small distance behind posterior end of ventral ganglion.
Posterior fins	More on trunk than tail, and end at seminal vesicles.	More on tail than trunk, and extend to seminal vesicles.	More on trunk than tail, and extend to seminal vesicles.
Collarette	Very small.	Noticeable.	Well developed.
Seminal vesicles	Far from tail fin and close to posterior end of posterior fins.	Touching both tail fin and posterior fins.	Touching both tail fin and posterior fins.
Ovaries	Short, extend to anterior end of posterior fins. Ovulae large and in small numbers.	Extend forward of anterior end of posterior fins. Ovulae regular in size and numerous.	Short, extend to anterior end of posterior fins. Ovulae small, filling ovaries.

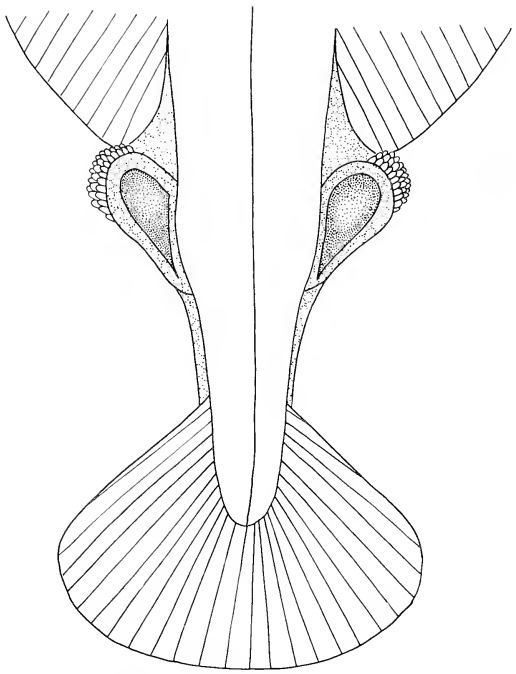

FIG. 6. *Sagitta tasmanica* Thomson, seminal vesicles, ventral view.

those of *S. neglecta* Aida (Fig. 9), and they belong to the "*bedoti*-type" (Tokioka, 1939). To compare the seminal vesicles of *S. euneritica* n. sp. with those of *S. friderici* Ritter-Zahony, see Tokioka, 1955, and Furnestin, 1953 and 1957; and to compare with *S. setosa* Müller see Furnestin, 1958.

The ovaries almost fill the width of the body and extend up to the anterior end of the posterior fins. The ovulae are not as large as those in *S. setosa* and they completely fill the ovaries.

The ecology of this species is very similar to *S. setosa* and *S. friderici* which are also found in coastal waters. In the California region *S. euneritica* n. sp. appears in large numbers (thousands per sample) in the neritic areas. In some places they are carried offshore by local superficial currents or eddies. In these cases the total number per haul gradually decreases as the distance from shore increases.

Table 3 gives the meristic characters and armature formulae.

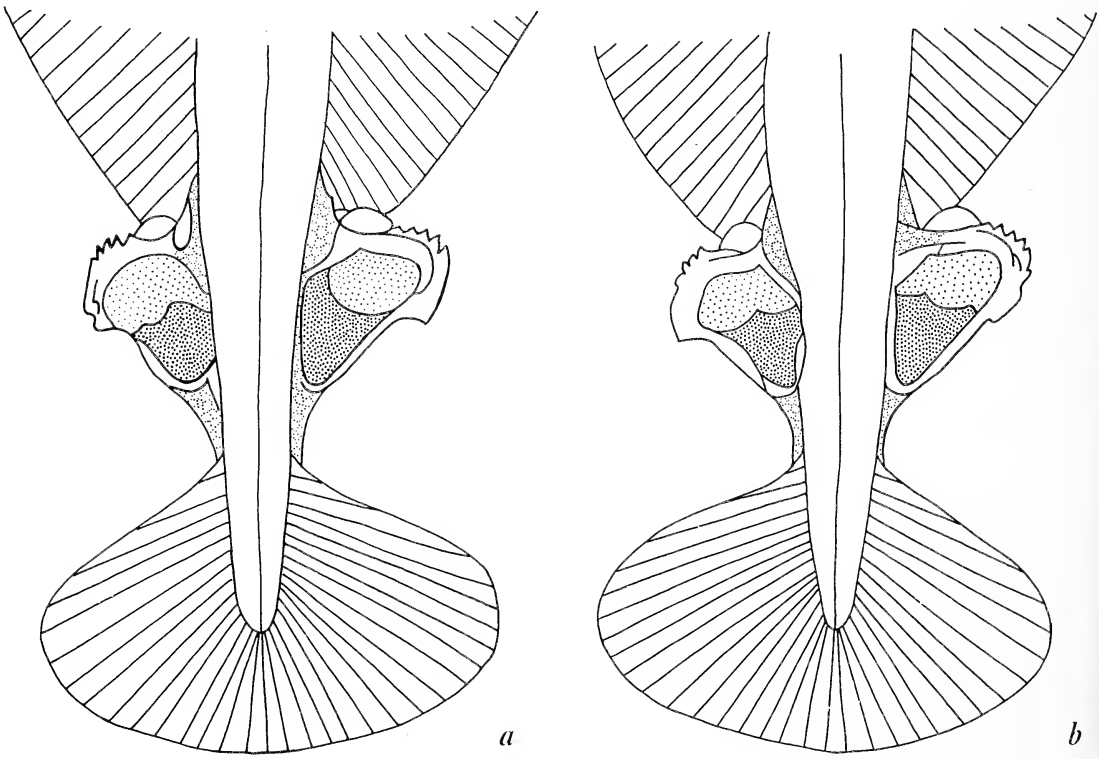

FIG. 7. *Sagitta pacifica* Tokioka. *a,* Seminal vesicles, dorsal view; *b,* ventral view.

It appears that *S. euneritica* n. sp. is closely related to *S. setosa* Müller and *S. friderici* Ritter-Zahony, but there are several points of difference as shown in Table 4 and Figure 10.

DISTRIBUTION: In the collections studied, CalCOFI cruises 5405 and 5804, it occurred close to shore from Cape Mendocino to Punta Eugenia in Baja California. Dr. Fager of the Scripps Institution collected some specimens using a hand-operated dredge net, when diving off the Tijuana River mouth (June, 1958) at a 50-ft. depth and also south of Scripps Pier (August, 1958) at 20- and 26-ft. depths.

Bieri (1957 and 1959) recorded this species as *S. friderici* ? in the same area along the coasts of North America extending south to the waters of Peru and Chile.

HOLOTYPE: USNM no. 29917.
PARATYPES: USNM no. 29918.

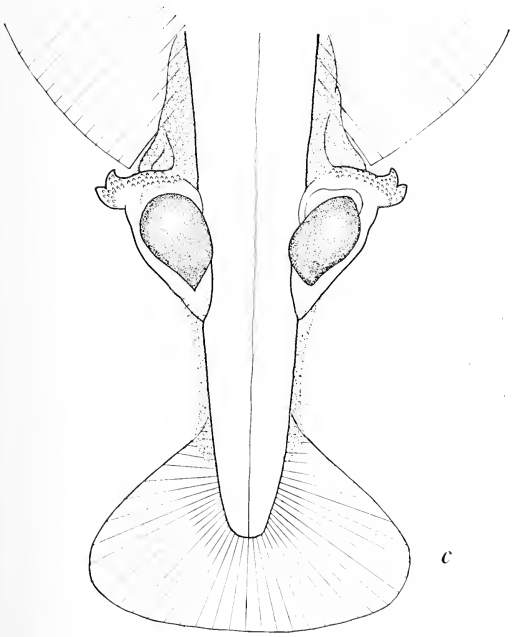

FIG. 7*c*. *Sagitta serratodentata* Krohn, seminal vesicles, dorsal view.

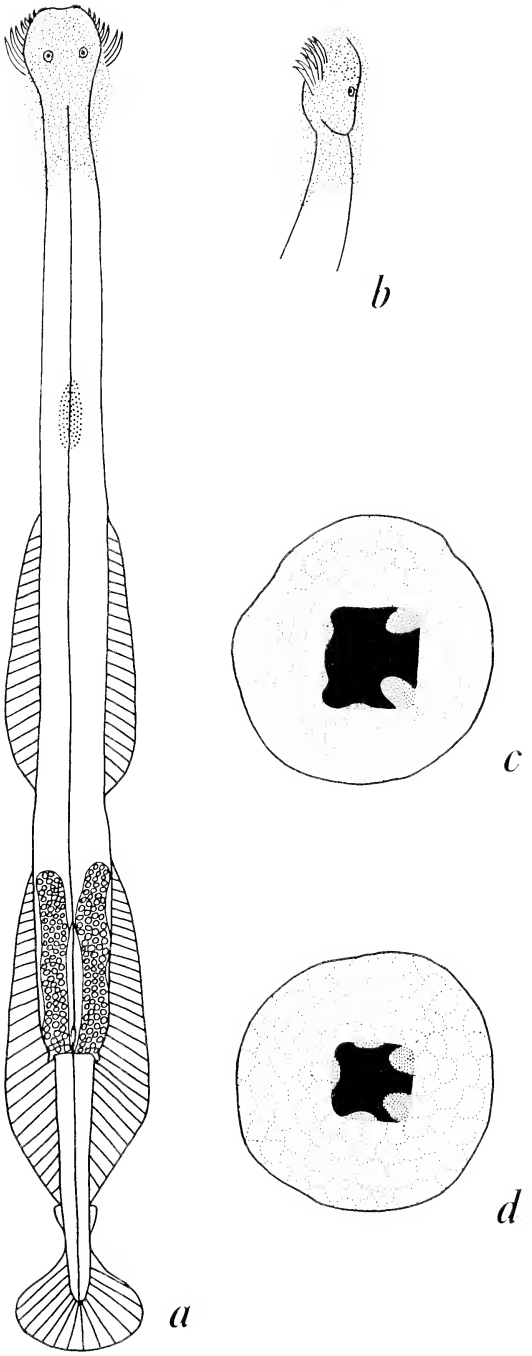

FIG. 8. *Sagitta euneritica*. *a*, Dorsal view; *b*, lateral view; *c*, left eye, mature specimen; *d*, left eye, immature specimen.

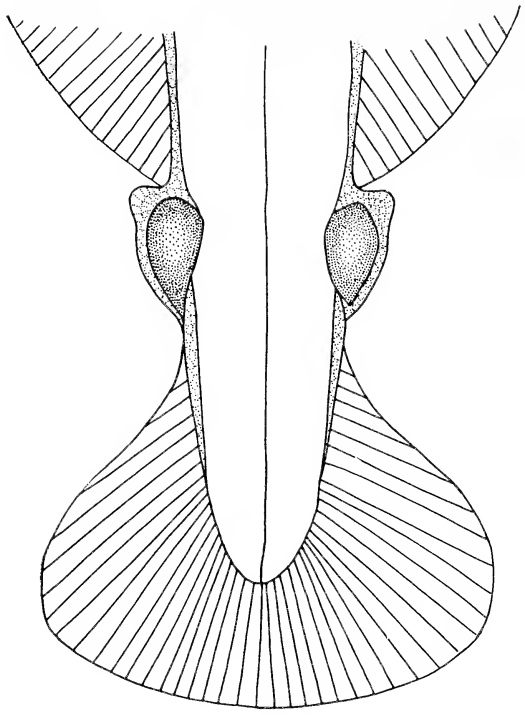

FIG. 9. *Sagitta euneritica,* seminal vesicles, dorsal view.

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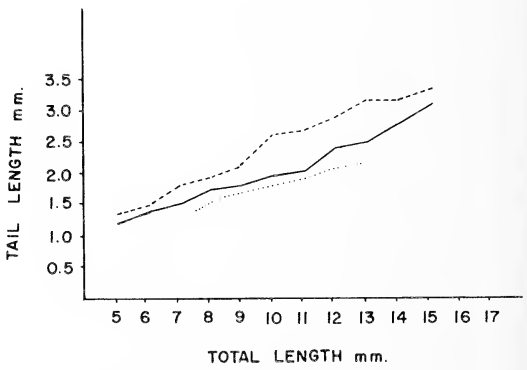

FIG. 10. Relation of total length to tail length. *S. euneritica,* ——; *S. friderici,* -----; *S. setosa,* ..... According to records of Ritter-Zahony, 1911*a*, Faure, 1953, Tokioka, 1955, and Furnestin, 1958, for *Sagitta friderici* Ritter-Zahony. Furnestin, 1958, and Ritter-Zahony, 1911*b*, for *Sagitta setosa* Müller.

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Polydora rickettsi, a New Species of Spionid Polychaete from Lower California

KEITH H. WOODWICK[1]

ONE COMPLETE POLYCHAETE SPECIMEN and two fragments collected by E. F. Ricketts in 1940 from Cape San Lucas, Lower California, are described here as members of a new species. The individuals concerned were taken from the tubes of *Spirobranchus incrassatus* Mörch, a serpulid polychaete. The new species resembles other polydorids in some characteristics, but is significantly different from all known species; the differences are discussed below.

Polydora rickettsi, n. sp.

The body is flattened in shape in the anterior segments, becoming more rounded posteriorly. The posterior end is not sharply tapered but is only about half the width of the first few segments. The modified 5th segment is greatly enlarged.

The complete specimen measured 10.0 mm. in length and included 104 segments. The anterior and posterior regions have a brown surface pigmentation, anteriorly along the lateral edges of the prostomium and posteriorly on all surfaces of the five prepygidial segments.

The rounded prostomium (Fig. 1) with its lateral lines of pigment produces an anterior end closely resembling that of the common California spionid, *Boccardia proboscidea* Hartman (1940). The greatly pronounced caruncle extends to the anterior margin of the modified 5th segment. There is a slight fold in the caruncle in the region bordered by the posterior half of the palpal bases but there is no nuchal tentacle. The eyes were not visible and may have been faded by the preservative, although the body pigmentation was not greatly affected.

The thick palpi are short, being equal in length to the first seven segments of the worm; they are tapered at the distal end. In dorsal view the peristomium is barely visible lateral to the palpi.

The 1st segment lacks notosetae but the notopodial lobe is present. The lobe is very small and is crowded in at the lateral edge of the palpal base. The neuropodial lobe is shifted dorsally but remains ventral to a line created by the notopodial lobes of the 2nd, 3rd, and 4th segments. These segments have notopodial and neuropodial lobes and setae. Their septal lines are erased dorsally by the presence of heavy longitudinal muscles paralleling the caruncle.

The enlarged 5th segment has a heavy musculature which overlaps most of segment 6 and part of segment 7 dorsally (Fig. 1). Anteriorly it crowds segment 4 and has a small anterior roll or cuff in that region. The heavy muscle bands associated with the specialized setae orient from the anterior lateral portion of the segment to the posterior median line. The anterior dorsal capillary setae precede the row of specialized setae. The latter have a main falcate tooth and a sharply curved pointed accessory tooth. There also is a flange located laterally on the main tooth at the level of the accessory tooth (Figs. 2, 3, 4). The companion setae are smaller plumose setae (Fig. 6). There is a very poorly developed bundle of neuropodial capillary setae. These are difficult to see and ordinarily are not taken when the specialized setae are removed for further study.

The 6th segment is about half the size of the 8th and the setal lobes are poorly developed.

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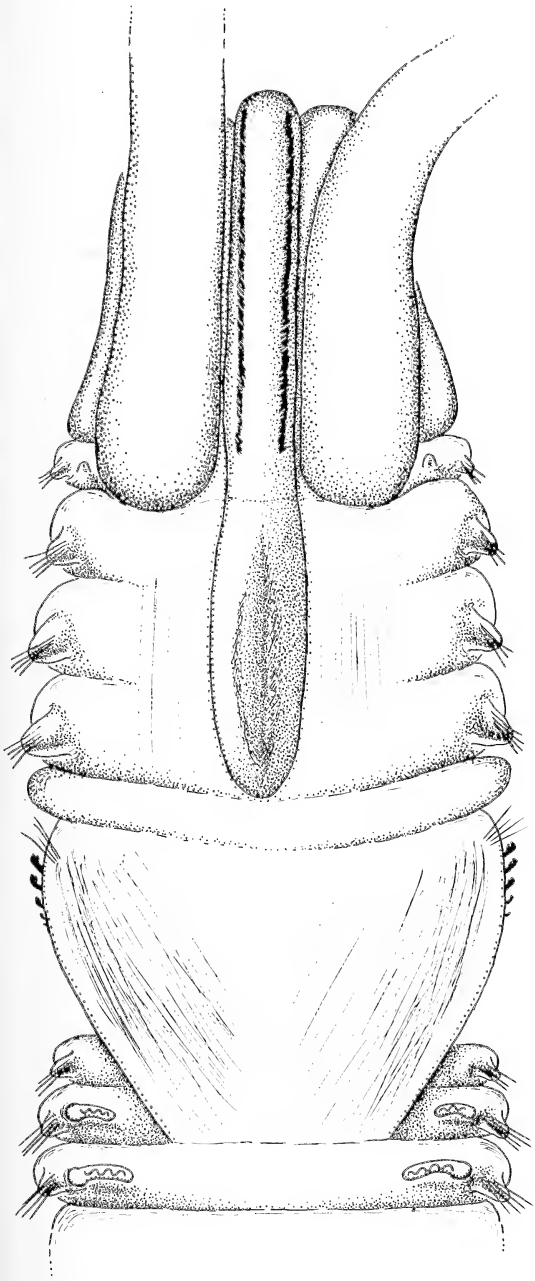
FIGS. 1–7. *Polydora rickettsi,* n. sp. 1, Anterior end, dorsal view (× 144); 2, 3, 4, specialized setae of modified 5th segment, new, worn, greatly worn, each at a different angle (× 555); 5, ventral hooded hooks from the 7th segment (× 900); 6, companion setae from modified 5th segment (× 1800); 7, pygidium, in posterior dorsal view (× 120).



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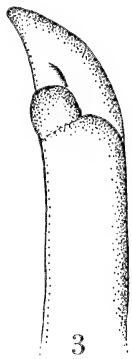

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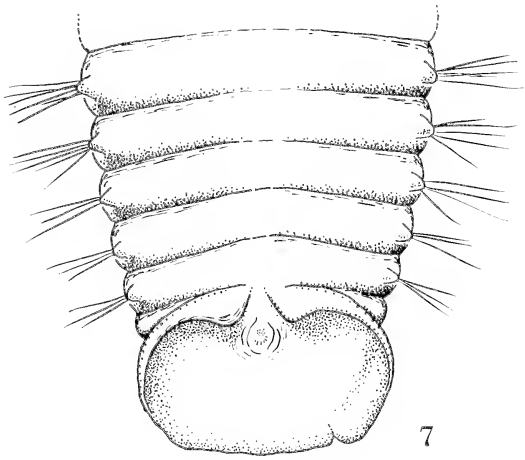

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TABLE 1

COMPARATIVE CHARACTERISTICS

SPECIES	PROSTOMIUM	LENGTH OF CARUNCLE	BRANCHIAE	FIRST SEGMENT NOTOSETAE	POSTERIOR SEGMENTS, NEUROPODIAL SPINES	HABITAT
Polydora rickettsi n. sp.	rounded (lateral pigmentation)	to the 5th segment	begin 7th, large to 30th	absent	absent	*Spirobranchus* tube
Polydora hoplura	bifid	to the 3rd	begin 7th, to 10th–20th last	absent	present (boathook)	shell of *Balanus*, sponges; shore, bottom of ship
Polydora giardi	bifid	anterior end or middle of the 4th	begin 10th, to 25th	present	absent	shale coralline algae
Polydora anoculata	bifid	to the 4th or 5th	begin 11th or 12th	present	absent	broken shells, *Amaroucium*
Polydora ciliata	weakly bifid	to the 3rd or mid-2nd	begin 7th, to 10th last	absent	absent	burrow in shells of many forms

The dorsal septal line is broken by the oblique muscular bands of the 5th segment. The muscles also reach into the 7th segment, but the latter is nearly full-sized and holds the 1st gill (not fully developed), and also the first representation of the distally bidentate neuropodial hooded hooks (Fig. 5). In these neuropodial setae the main tooth forms an oblique angle, with the shaft following the angle measurement system of Söderström (1920). There are seven hooded hooks mixed with capillaries in the 7th segment; the capillaries do not persist.

The branchiae are full-size from the 8th segment to the 30th; they decrease in size to the 66th segment, where they are continued posteriorly as small papillae.

There are no posterior notopodial hooks or spines.

The disclike pygidium has a dorsal notch and, although not broadly flared, is greater in diameter than the prepygidial segments (Fig. 7).

DISCUSSION

Other polydorids reported from Mexican waters are discussed in Rioja (1943) and include *Polydora armata, P. ciliata, P. cirrosa, P. commensalis, P. flava, P. giardi, P. heterochaeta, P. ligni, P. socialis,* and *P. tricuspa.* Of these species *P. giardi* and *P. ciliata* most closely resemble *P. rickettsi* in characteristics and habitat. Some of the characteristics of these three forms, and of the morphologically similar *P. hoplura* and *P. anoculata* from other waters, are compared in Table 1. In addition to the contrasting characters shown in the table the five species have characteristics in common, including the following: specialized setae with a main falcate tooth and a subterminal accessory tooth in the 5th segment, hooded hooks beginning in the 7th segment, disclike pygidia, and the absence of nuchal tentacles.

TYPE MATERIAL: The holotype and additional material have been deposited in the polychaete collections of the Allan Hancock Foundation, University of Southern California.

TYPE LOCALITY: *P. rickettsi,* known only from the tube of *Spirobranchus incrassatus* Mörch, was collected March 18, 1940, at Cape San Lucas, Lower California, Mexico.

BIOLOGY: The specialized setae of the 5th segment, which are like those present in other boring polydorid species, and the habitat of

this worm suggest the species to be a boring form. Steinbeck and Ricketts (1941: 368) report the following for *Spirobranchus incrassatus,* the associated serpulid species, "An important feature of the low intertidal landscape at Cape San Lucas, where the anastomosing calcareous tubes of this large and spectacular worm encrust the rocks."

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An Ecological Perspective of Marcus Island, with Special Reference to Land Animals

SHOICHI F. SAKAGAMI[1]

MARCUS IS A SMALL, remote reef island in the vast western Pacific. It is located at N. 24° 20′, E. 154° (Bryan, 1903), being 1,000 km. ENE. of Farallon de Pajaros (the northernmost of the Mariana Islands), 1,300 km. E. of Iwo Jima, and a little farther WNW. of Wake (Gressitt, 1954).[2] Prior to World War II the island was a Japanese dependency. Now it is a part of the Trust Territory of the United States, but there is no active establishment upon it except for a weather station belonging to the Central Meteorological Observatory of Tokyo. Through the courtesy of the Observatory, I had an opportunity to visit the island, together with Dr. N. Kuroda of the Yamashina Ornithological Institute (birds) and Mr. M. Yamada of our Institute (marine invertebrates), during April 30 to May 6, 1952, and to observe its land biota. Although our observations were not extensive because of lack of sufficient time, I believe that the results are worth publishing because of our scanty knowledge of the ecology of the smaller Pacific islands and the lack of comprehensive biological research on this island since Bryan's visit in 1903.

TOPOGRAPHY AND SOIL TEXTURE

Marcus Island is a raised atoll formed on an elevation of submarine mountains in northern Micronesia. As seen in Figure 1, it is triangular, with south and north shores of about 2 km., and the northwest shore a little longer. The lagoon between the island and the fringing reef is about 200 m. on the NW. shore but is much narrower on the S. and E. shores (Fig. 2). All of the shores are lined by sandy beaches, except at the northernmost parts of the NW. coast, where the old, already mineralized reef occurs along the beach (Figs. 1, 3). The reef is connected with the outer ocean by means of two indentations in the E. and S. shores, respectively. Only the southern indentation is used, however, as the harbor for landing by boats (Fig. 1*c*), as large ships cannot approach the harbor because of the dangerous underwater reef. The island is very flat. Formerly, the highest altitude was reported as 22 m. by Bryan (1903), but now, because of the leveling undertaken during the war, it is only 7 m. near the northern cape. Also, the trace of an old lagoon discovered by Bryan was filled up with earth by the wartime activities (Matsubara, private communication to the writer). A runway of about 1,700 m. running across the island parallel with the NW. shore and a broad road near the southern shore now divide the island into three areas, the NW. zone, the S. zone, and the E. triangle (Fig. 1). As previously mentioned, the weather station and accompanying facilities are the only establishments now active on the island. But remains of ruined buildings constructed by both Japanese and American military forces during or after World War II are scattered everywhere. The earth consists exclusively of coral sand and pebbles. The latter vary in dimensions from mere large sand grains to pieces of gravel more than 5 cm. in length (Fig. 10). Accumulation of humus was observed only in the E. triangle, where the vegetation was relatively well developed.

In summary, Marcus is extremely poor in land area, soil texture, and topographical diversities. How such a poverty reflects on the land biota will be described subsequently. It must be men-

[1] Contribution No. 486 from the Zoological Institute, Faculty of Science, Hokkaido University, Sapporo, Japan. Manuscript received March 19, 1959.

[2] Location of the island differs slightly from one record to another: N. 24° 17′ 30″, E. 153° 58′, according to the notification by the Tokyo Prefectural Office (1898); and N. 24° 17′ 35″, E. 154° 4′ 30″, and N. 24° 17′ 02″, E. 154° 1′, respectively, according to observations by two Japanese cruisers, the *Kasagi* and the *Takachiho* (Yoshida, 1902).

tioned also that the fringing reef may serve to a certain degree as a physical barrier against the immigration of various terrestrial organisms.

CLIMATE

Thanks to the occurrence of a weather station, which initiated its postwar activities in April, 1951, we possess a rather precise picture of this mere heap of sand and pebbles in the vast ocean. Means of maximum, mean, and minimum daily temperatures during my stay were 25.9°, 22.7°, and 21.0° C., respectively; the average annual trends of various climatic factors are shown in Table 1. From these data,

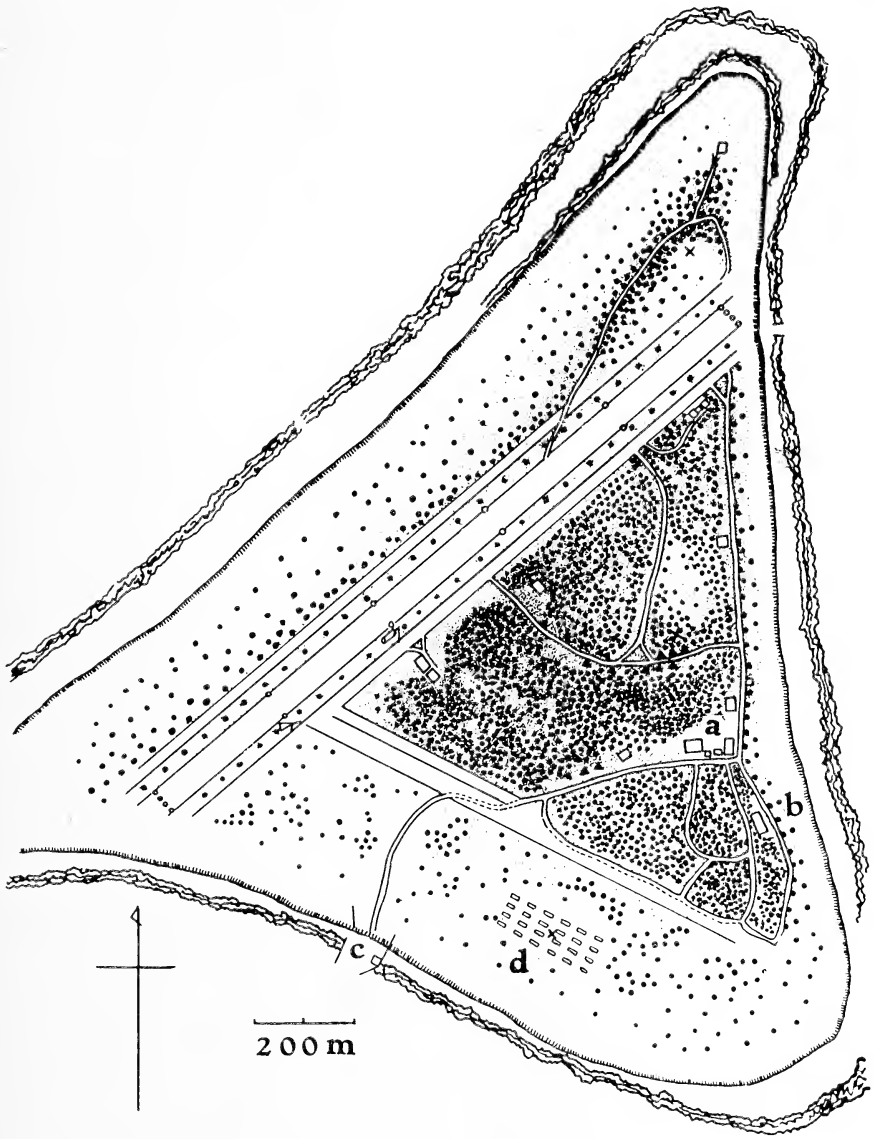


FIG. 1. Marcus Island. Drawing based upon a map used in the Observatory, showing *Messerschmidia* and *Pisonia* (dots), papaya (triangles), coconut palms (crosses), buildings (including ruined ones). Minute dots denote the density of *Ipomoea*. *a*, Office of weather station; *b*, lodging house; *c*, harbor; *d*, ruined barracks.

TABLE 1

CLIMATE OF MARCUS ISLAND

(The data are the averages obtained during 1952–4. Maximum and minimum values are the extreme ones noted during the four years.)

	TEMPERATURE (°C.)			MEAN RELATIVE HUMIDITY (%)	WIND VELOCITY (m/sec)		RAINFALL (mm.)	
	Max.	Mean	Min.		Max.	Mean	Total	Max/hr
January	29.7	22.4	17.2	72	18.3	7.6	66.9	28.5
February	28.5	22.4	16.3	75	18.1	7.5	53.5	25.7
March	29.9	23.0	18.0	76	18.4	7.8	39.5	10.9
April	31.9	24.8	18.4	78	17.6	8.1	37.8	8.7
May	33.3	26.3	19.8	78	13.2	5.7	48.7	15.9
June	33.8	28.1	23.1	75	12.4	4.5	43.0	23.0
July	35.3	27.3	22.8	78	16.4	6.0	252.8	59.2
August	33.7	27.3	21.8	79	15.6	6.4	189.1	23.9
September	35.3	27.9	22.8	76	16.5	7.3	82.4	31.0
October	33.5	26.8	21.9	78	18.9	7.1	117.8	28.6
November	34.2	26.0	22.0	77	18.5	7.1	45.7	12.3
December	31.6	23.5	18.5	73	21.6	8.6	66.1	16.5

Warmth Index, W = 245.8° C. Humidity Index, K = 5.4.

it is suggested that Marcus has a relatively dry climate in spite of its oceanic position. Actually, it occupies an intermediate position between Aw and Bs of Köppen's climate formula, although the differentiation of seasons is relatively less conspicuous. According to the climate classification by Kira (1953), who established an excellent climate system based upon two very simple indices, warmth and humidity,[3] the island lies at the cool-arid corner of his type B_6 (tropical semiarid climate). From the climographs and hithergraphs shown in Figure 11,[4] together with those of Chichijima (Bonin Is.), Yap, and Honolulu, the annual cycle can be roughly divided into two seasons, namely, October to April, which is dry, cool, and windy; and May to September, which shows the opposite trends. Bryan also reported the danger of landing during October to April, because in that season the waves beat violently upon the reefs and shores. This was also confirmed in my trip by the staff of the weather station. As the island is located in the western part of the northeast trade-winds belt, the prevailing winds are from the east, but certain northern trends mingle during October to April. Furthermore, the influence of typhoons, which frequently visit in September and October, must not be overlooked. For instance, the island was completely washed by violent waves from the south to the northwest and eastern shores, when typhoon Sara passed over the island in October, 1951. Maximum wind speed was 40.5 m/s; maximal instantaneous speed, 50.9 m/s; rainfall, 154.9 mm. (For the effects of typhoons, see also the Appendix.)

The climatic features mentioned above may be well explained by the location and topography of the island. Gressitt (1954) mentioned that there was occasionally found a dry local climate within the generally wet, oceanic climate of Micronesia, especially in low islands

[3] Warmth Index: $W = \sum_{i} (t\text{-}5)$, where t = mean temperature of each month; i = number of months when t>5. Humidity Index: K = 2P/(W+140), where P = annual rainfall, W = Warmth Index.

[4] In the hithergraph, high rainfall in July is mainly caused by an abnormally rainy weather in 1953 (500.2 mm.). In other years, 76.8 (1951), 177.1 (1952), 144.7 (1953), and 189.3 (1954), respectively.

and atolls. Its minute size and the poor conservation of water by coral sand may be the main causes of the dry climate of Marcus, as in Wake Island with a similar topography and climate. Consequently, the climate of Marcus is, in spite of its subtropical position, inadequate to support a luxuriant flourishing of organic and ecological diversities. (Rain is the only source of fresh water in the island.)

FLORA AND VEGETATION

The flora of Marcus has been reported by Yabe (1902), Bryan (1903), and Tuyama (1938). The plants collected by me were kindly determined by Dr. Tuyama. They are listed in Table 2, together with those reported by the earlier publications. Comparison of the present flora with those of previous studies will be discussed later. Here the discussion is limited to the plants collected by myself. Judging from the size and topography of the island, I believe that the collection of the plants which were growing there during my stay is almost complete. It is obvious from Table 2 that the flora is extremely poor both in number of species and in endemism. Most of the species are either cosmopolitan or tropicopolitan, or are those which behave as dominants in many communities because of their great vigor. In other words, we find here no more than a typical example of the poor flora of oceanic atolls.

The structure of the vegetation, too, is very simple. The arboreal stratum was composed of *Messerschmidia* and *Pisonia* mixed in an approximate ratio of 7:3, although the latter was relatively scarce outside the E. triangle (Figs. 1, 4). The density and resulting coverage was highest in the E. triangle and next highest along an abandoned road in the northern section of the NW. zone. In addition to these two dominants, about a dozen papayas were observed

TABLE 2

SYNOPTIC TABLE OF PLANTS RECORDED FROM MARCUS ISLAND

YABE (1902)	BRYAN (1903)	TUYAMA (1938)	SAKAGAMI (Identified by Dr. Tuyama)
Species recorded at least in two occasions			
Tounefortia argentea	*Tounefortia servicea*	*Messerschmidia argentea*	*Messerschmidia argentea*
Cocos nucifera	*Cocos nucifera*	*Cocos nucifera*	*Cocos nucifera*
Morinda citrifolia	Rubiaceae gen. sp.	*Morinda citrifolia*	
		Carica Papaya	*Carica Papaya*
		Pisonia grandis	*Pisonia grandis*
Portulacea oleracea	*Portulacea lutea*	*Portulacea oleracea*	*Portulacea oleracea*
Tobacco	tobacco		*Nicotiana Tabacum*
Boerhaavia repens		*Boerhaavia repens*	
		Ipomoea pes-caprae	*Ipomoea pes-caprae*
		Eleusine indica	*Eleusine indica*
Species recorded only once			
Graminae gen. sp.	*Euxolus* sp.	*Dactyloctenium aegypticum*	*Bryophyllum pinnatum*
	Panicum pruriens	*Setaria lutescens*	*Pennisetum setosum*
	Rottboellia sp.	*Syntherisma sangunalis*	*Cenchrus echinatus*
	a low trailing herb	*Scaevola frutescens*	*Erigeron sumatrensis*
		Malvastrum tricupidatum	*Euphorbia hirta*
	an unknown herb	*Lepturus repens*	*E. prostrata*
			Sonchus oleraceus
			Boerhaavia diffusa

FIG. 2

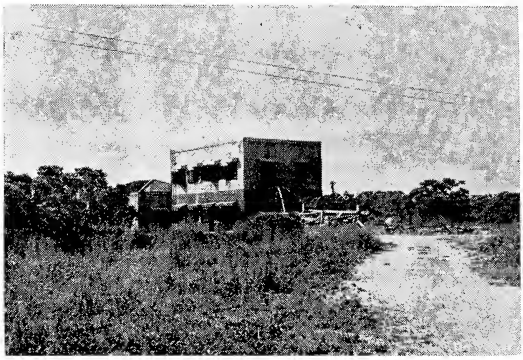


FIG. 5

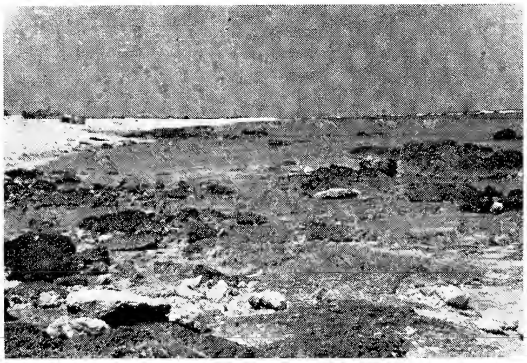


FIG. 3

FIG. 6

FIG. 4

FIG. 7

FIGS. 2–10. Some topographical and biological aspects of Marcus. Explanation in text.

FIG. 8

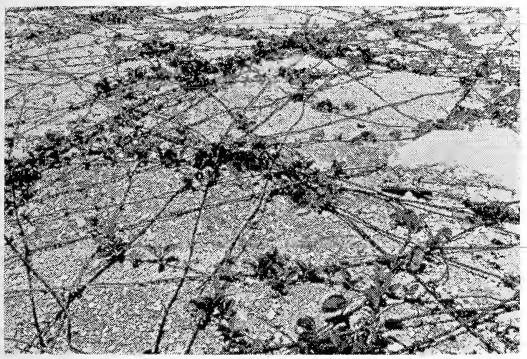


FIG. 9

along two paths penetrating the E. triangle (Figs. 1, 8). The coconut palm, which formerly had been the leading member of the arboreal stratum, was represented by only three undernourished saplings, as is indicated by the crosses in Figure 1.

The simplicity of the herbaceous layer was much more surprising. It was practically no more than an overwhelming dominance of *Ipomoea pes-caprae*. The density was also highest in the E. triangle, except its NW. section, but the stout runner extended its domain throughout the island except on the outermost margins of the sandy beaches. In the center of the E. triangle, this creeper constituted a pure community of about 1 sq. km., excluding all other herbs; there one could walk hundreds of meters on a thick bed of intermingled vines, both

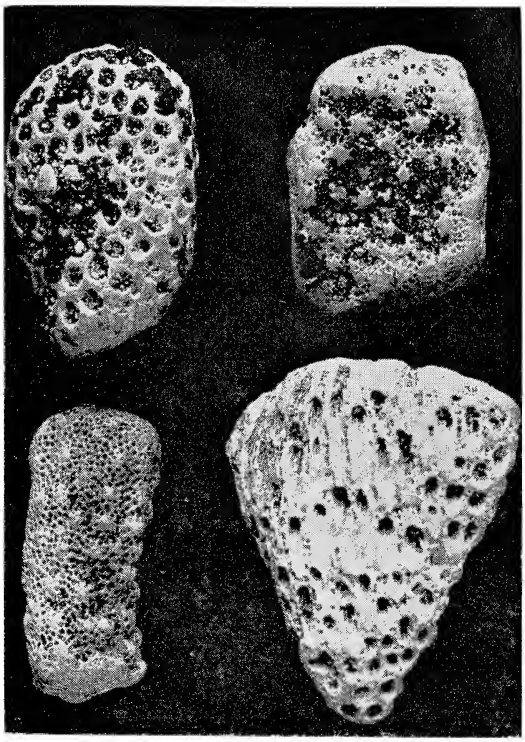


FIG. 10

living and withered, without touching the soil surface (Fig. 4).

Consequently, other herbs and grasses, although most of them were very vigorous weeds, grew only in limited areas, apparently where the pressure of *Ipomoea* was not conspicuous, namely, in wooded edges, roadsides, and the NW. section of the E. triangle. In such zones, *Portulaca* and *Cenchrus* were dominant members of the lower stratum, and *Pennisetum, Nicotiana, Eleusine,* and *Sonchus* of the higher one. The area richest in species was the confluent point of the runway and the other broad road, where most species of herbs and grasses were collected. On the other hand, no plants other than *Ipomoea* were discovered on the beaches (Fig. 9). From this description, it may be recognized that the island is extremely simple in both floristic and vegetational aspects.

FAUNA

The birds and mammals collected or observed in our survey were described by Kuroda (1954).

All other land animals collected or observed by me, or those later sent me from the weather station, are listed in Table 3, accompanied by notes on distribution and abundance. The following remarks will explain the data presented in the table.

1. The number of species given in parentheses after the names of the major taxonomic groups does not always coincide with the number listed under each group, because the familial characters were not determined for some specimens which were not caught or were lost before or during the preparation of our data.

2. Under the column showing range, the distribution of identified species in other districts is mentioned. In the majority, however, only the pattern of geographic distribution is given, using the following abbreviations: E, endemic at present; C, cosmopolitan; T, tropicopolitan, including Indo-Pacificopolitan; P, Pacificopolitan; and Pa, Palaearctic. These patterns are naturally very conventional, for the distinction among C, T, and P is often subjective.

3. Under the column showing abundance, the relative abundance of each species is shown with marks: ++, very abundant; ±, abundant; +, common; —, rare. The last observation may express not an actual rareness, but only a cryptic life-mode.

4. The distribution and relative abundance of each species in the various habitats (see the definition of A, B, etc., in the next paragraph) are indicated by O (for occurrence) or A (for abundance). Where holometabolic insects are concerned, the distribution is considered only with respect to adults, but in the sphingid and noctuid moths, only with respect to their caterpillars, inasmuch as the adults were collected only at lights.

5. The species observed but not collected are marked with an asterisk, and those which were only indirectly confirmed are marked with a dagger.

DISTRIBUTION OF ANIMALS IN VARIOUS HABITATS

In order to obtain a closer perspective with regard to the ecological distribution of animals listed above, the island was divided into the following habitat zones, based upon topography and vegetation (Fig. 12).

A: Areas with both arboreal and herbaceous strata (Fig. 4 and Fig. 5, back):
- A_1: Floor stratum, including earth surface and sites beneath gravel and stones.
- A_2: Herbaceous stratum, consisting of *Ipomoea* foliage alone.
- A_3: Arboreal stratum, consisting of *Messerschmidia* and *Pisonia* as dominants.

B: Areas without arboreal stratum, with relatively tall grass and herbs, and with poor development of *Ipomoea* (Fig. 5, left):
- B_1: Floor stratum corresponding to A_1.
- B_2: Stratum of short grass and herbs.
- B_3: Stratum of tall grass and herbs.

C: Areas with short grass and herbs alone; *Ipomoea* cover is more developed than in B (Fig. 5, middle):
- C_1: Floor stratum corresponding to B_1.
- C_2: Stratum of grass and herbs.

D: Areas largely exposed, with patchy development of grass and herbs; *Ipomoea* cover less developed than in C:

C′ (C'_1 and C'_2): Littoral zones corresponding to C and D in habitat structure. However, C'_1 consisted of scattered establishments of *Ipomoea* frontiers alone, and D′ is almost aphytic.

D′

H: Areas disarranged by human activities.

The relative size of these habitats was approximately A greater than or equal to C′ approximately equal to $D' > D > B$ approximately equal to C. The richness of each habitat in number of species and in ecological endemicity may be roughly estimated by comparing the total species number with the number of species found exclusively in each habitat (see Table 4). Conclusions derived from these data are:

1. With respect to vertical distribution, the floor strata are far richer both in species number and in ecological endemicity than are the upper strata. Apparently, this is caused by the poor development of vegetation in the latter.

2. Horizontally, A is the richest section in

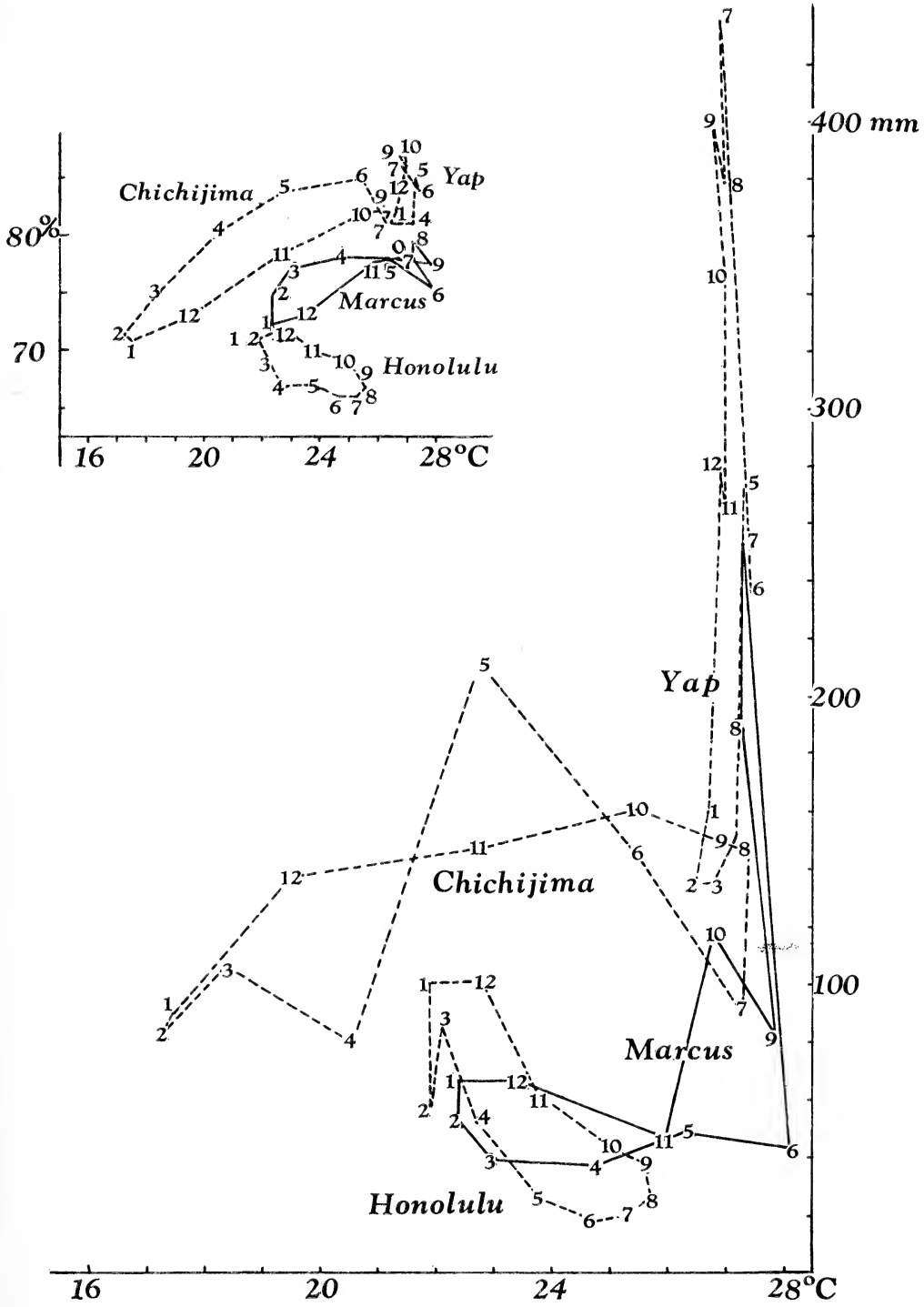


FIG. 11. Climograph (above) and hithergraph of Marcus, Chichijima (Bonins), Yap, and Honolulu.

TABLE 3

TERRESTRIAL MACROSCOPIC ANIMALS ON MARCUS ISLAND, EXCLUDING MAMMALS AND BIRDS

FAMILY	SPECIES	RANGE	ABUNDANCE	DISTRIBUTION AND RELATIVE ABUNDANCE IN VARIOUS HABITATS										
				A_1	A_2	A_3	B_1	B_2	B_3	C_1 C_2	D	C_1' C_2'	D'	H
Mollusca–Orthurethra (1)														
?	gen. sp.		—	O										
Annelida (1)														
Megascolecidae	?*Allolobophora* sp.		—	O										
Crustacea (6)														
Grapsidae	*Geograpsus grayi* (Millne–Edwards)	T	++	A	O	O	O			A	O	O		A
Coenobitidae	†*Coenobita* sp.		(±)							(O)				(O)
Porcellidae	*Armadillo* sp.		±	O										
	Porcellio sp. 1		—	O										
	Porcellio sp. 2		—							O				
	gen. sp.		—	O										
Myriapoda (2)														
Mecistocephalidae	*Mecistocephalus marcusensis* Miyoshi	E	±	O								O		
Henicopidae	*Lamyctes* sp.		—	O										
Arachnoidea–Araneae (6)														
Pholcidae	*Pholcus crypticoleus* Bösenberg & Strand	Pa	—											O
Salticidae	*Plexippus paykulli* Aud.	C	+	O			O			O	O			O
Heteropodidae	*Heteropoda venatoria* (L.)	T	+			O								O
Argiopidae	*Neoscona theisi* (Walckenaer)	T	++			A								
Arachnoidea–Acari (3)														
Oribatidae	gen. sp.		±								O	O		
Arachnoidea–Cheriferidea (3)														
Dithidae	*Ditha (Paraditha) marcusensis* (Morikawa)	E	—	O										
Chthoniidae	*Lechytia sakagamii* Morikawa	E	—	O										
Garypidae	*Geogarypus (Geogarypus) micronesiensis* Morikawa	E	—									O		
Apterygota (5)														
Entomohyridae	*Drepanocyrtus terrestris* Folsom	Hawaii	+								O			
	Sira jacobsoni Börner	P	±									O		
	Lepidocyrtus sp.		—									O		
Lepismatidae	*Ctenolepisma villosa* Escherich	Pa	—											O
Machilidae	*gen. sp.			O										

TABLE 3 (*Continued*)

FAMILY	SPECIES	RANGE	ABUNDANCE	DISTRIBUTION AND RELATIVE ABUNDANCE IN VARIOUS HABITATS											
				A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	D	C_1' C_2'	D′	H
Odonata (1)															
Libellulidae..	**Diplacodes bipunctata* Brauer	P	(+?)	(O)	(O)										
Orthopteroidea (13)															
Blattidae	*Periplaneta americana* (L.)	T	++												A
	P. australasiae (L.)	T	++												A
	?Blatta sp.		—	O											
	?Blattella sp.		—									O			
	Leucophaea surinamensis (L.)	T	—	O											
Anisolabidae	*Anisolabis martima* (Borelli)	C	+	O								O	O	O	
	Euborella annulipes (Lucas)	C	+	O			O			O		O			
Labiduridae..	*Labidura* sp.		±									O			
Gryllidae	*Landreva clara* Walker	T	++	A			O			A		O			
	Ornebius sp.		+	O											
Locustidae	*Aiolopus tamulus* (Fabricius)	T	+				O			A	O	A			
	Locusta migratoria ssp.		++		A	A		O	O	O	O	O			
Embioptera (1)															
Oligotomidae	*Oligotoma saundersi* Westwood	Oriental	++							O		A			
Psocoptera (1)															
?	gen. sp.		+									O			
Hemiptera (9)															
Coccidae	*Coccus hesperidum* L.	T	+		O	O		O			O				
Aphidae	*Aphis gossypii* Glover	C	+	O							O				
Coreidae	*Liorhyssus hyalinus* (Fabricius)	C	±						O						
Miridae	*Cyrtopeltis (Nesidiocoris) tenuis* (Reuter)	T	±						O						
Nabidae	*Nabis capsiformis* Germer	C	+				O			O		O			
Lygaeidae	*Nysius pulchellus* (Stal)		+				O			O		O			
	Pachybrachius nigriceps (Dallas)	P	±				O			O		O			
Anthocoridae	*Gardiastethus fulvescens* (Walker)	T	±												O
Cydnidae	*Geotomus pygmaeus* (Dallas)	T	±	O			O			O		O			
Lepidoptera (5)															
Sphingidae	*Herse convolvuli* L.	C	+		O						O				
Noctuidae	*Prodenia litura* Fabricius	T	++		A						O				
	Achaena melicerta Drury	T													
Arctidae	*Utethesia pulchella* ssp.	P	++			A									
?	a micro-moth		±			O									

TABLE 3 (*Continued*)

FAMILY	SPECIES	RANGE	ABUNDANCE	DISTRIBUTION AND RELATIVE ABUNDANCE IN VARIOUS HABITATS															
				A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	D	C_1'	C_2'	D′	H			
Coleoptera (7)																			
Curculionidae	*Oxydema fusiforme* Wollaston	P	—	O															
	Cylas formicarius Fabricius	T	±	O	O		O	O		O	O								
	Calandra oryzae L.	C	±													O			
Tenebrionidae	*Tribolium castaneum* (Herbst)	C	±													O			
Oedemeridae	*Eobia chinensis* Hope	Pa	++			A										A			
Coccinellidae	*Scymnus* sp.		—	O															
Elateridae	?*Harmirius* sp.															O			
Hymenoptera (6)																			
Sphecidae	*Sceliphron cementarium* (Drudy)	Nearctic	+			O										O			
Vespidae	†Eumeninae gen. sp.																		
Formicidae	*Solenopsis geminata* Fabricius	T	—						O	O	O								
	Tapinoma melanocephalum Fabricius	T	++	A	O	O	A	O	O	A	O	O	O	O		O			
	Lasius niger ssp.	Pa	++	A	O	O	A	O	O	A	O	O	O	O		O			
	Tetramorium caespitum L.	Pa	—	O															
Diptera (11)																			
Syrphidae	*Ischiodon scutellaris* Fabricius	T	+		O			O	O										
Drosophilidae	*Drosophila melanogaster* Meigen	C	±		O	O			O	O						O			
Anthomyidae	*Atherigona excisa* Thompson	P	++			O										A			
Muscidae	*Musca domestica* L.	C	+													O			
	Lucilia sericata L.	C	+		O	O										O			
Sarcophagidae	*Parasarcophaga (Liosarcophaga) misera* (Walker)	C	+		O	O										O			
Phoridae	*Aneurina* sp.		+													O			
Ephydridae	gen. sp.		—			O										O			
Agromyzidae	gen. sp.		—			O										O			
Sphaeroceridae	gen. sp.		—													O			
Dolichopodidae	gen. sp.		±			O			O							O			
Reptilia																			
Scincidae	*Cryptoblepharus boutonii nigropunctatus* (Hallowell)	Bonins	++	A	O	O	A	O		A	O	A	O	O		A			
Geckonidae	*Gehyra variegata ogasawarasimae* Okada	Bonins	±	O												O			

both species number and ecological endemicity. This is natural because this habitat occupies more than half of the island and is biologically the most productive and stable zone. It must be mentioned, however, that A has a relatively poor fauna, depending on its very simple vegetation, as in C'_2.

3. D′ is obviously the poorest habitat because of its aphytic conditions; this conclusion, of course, pertains only to our observations upon the macroscopic animals. Bio-economically, this habitat really is the front of the marine littoral ecosystem extending into the land. On the other hand, the relatively rich number of species found in B and C, in spite of their small size, is apparently due to their ecotonal character.

4. The poor differentiation of C_1 and B_1 (compare the two serial orders in Table 4) may be understood if these strata are considered as a mere extension of an ecological gradient, of which the peak lies in A_1. The structure of the floor fauna varies, therefore, at first when the plant cover almost disappears in D. C'_1 has also a few characteristic species corresponding to its littoral nature.

DESCRIPTION OF EACH HABITAT

The several habitats distinguished above must not be considered to be like cages or walled areas which confine various inhabitants within them. They are merely devices of a coordinated system for the clear understanding of the ecological make-up of the island. Eventually, certain species pass freely from one habitat, or from one stratum, to another. Before describing each habitat and its inhabitants, brief notes will be given concerning these mobile species.

The rat, *Rattus rattus* ssp., is the only mammal inhabiting the island. Formerly, the staff of the weather station kept cats which controlled a considerable number of rats. In the absence of any intensive controls, the rats are now fairly abundant and their activities were traced everywhere in the island.

The skink, *Cryptoblepharus,* and the land crab, *Geograpsus,*[5] were also seen everywhere, except B_3 and D′ in the case of the former species, and except B_2, B_3, C_2, C'_2, and D′ in the latter one. Both can climb up *Messerschmidia* and *Pisonia* to fairly high twigs. They even appear in the upper stories of buildings: crabs were often observed when they were crawling up vertical walls nearly to the ceiling. It is certain that these animals, one as a predator and the other as a scavenger, play important roles in the bio-economy of the island.

Two ants, *Lasius* and *Tapinoma,* may be added to the list of widely roaming species. They were observed utilizing the runners of *Ipomoea* to invade even into area C'_2, where other animals were scarcely seen. Although it is a relatively sedentary creature, a cricket, *Landreva,* was collected in almost every floor stratum except C_1 and D′. Its songs could be heard in the daytime, but they were more impressive at night, dominating this tiny bit of land in the midst of the immense ocean.

Setting these mobile species aside, some characteristic features of each habitat will be outlined.

Zone A is the largest, richest, and most stable habitat in the island. This is also the only area where the formation of humus is relatively conspicuous. Consequently, because of the lodging it affords various cryptic animals (roaches, land-isopods, myriapods, etc., under stones, *Oxydema* in decayed wood), A_1 has the richest fauna in the island. A_2 consisted of *Ipomoea* foliage alone. *Sphinx, Prodenia,* and *Coccus* were the major pests of the vigorous creeper. *Prodenia,* especially, was locally very abundant, and considerable damage was observed, as is shown in Figures 6 and 7.

Locusta and *Utetheisa,* both feeding on *Messerschmidia,* surprised us by their spectacular abundance. The adults of *Utetheisa* are active irrespective of diurnal rhythm. In daytime, they were seen everywhere in the A zone, feebly fluttering from one tree to another. At night they swarmed abundantly around lamps. The first instar larvae live concealed within the young sprouts (Fig. 14); older ones feed on exposed leaf surfaces, and pupae are seen near the tips of leaves, in a thin hammock spun by themselves (Fig. 13).

[5] As most recorded genera are represented by a single species, only generic names will be given in the following descriptions.

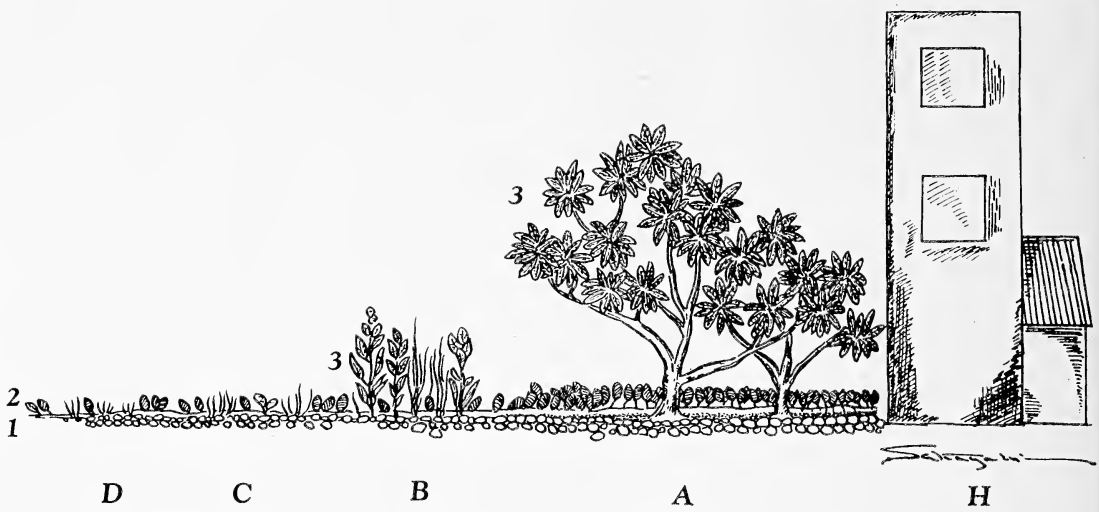


FIG. 12. Distinction of various habitats based upon vegetation and topography.

Adults and nymphs of all stages of *Locusta* were collected on *Messerschmidia.* From their extreme abundance, high activity, and great voracity, I have the impression that this population might change from *phasis solitaria* to *phasis transiens.* Inside still younger buds of *Messerschmidia,* a small cricket, *Ornebius,* was often discovered. They always directed the head and antennae upward (Fig. 15), and when disturbed rolled down very quickly into the earth.

Coccus were also found in *Pisonia* and, especially in papaya, were eagerly visited by two milkers, *Lasius* and *Tapinoma.* Moreover, various flies and their predators, *Heteropoda* and *Neoscona,* were abundant throughout the arboreal foliage. Considerable numbers of the latter species were found in nests of an introduced American wasp, *Sceliphron.*

Corresponding to their ecotonal nature, B and C were relatively rich in number of species but possessed only two characteristic bugs: *Cyrtopeltis* on tobacco and *Liorhyssus* on *Sonchus.* The activities of skinks and land crabs decrease in B due to a relatively thick growth of herbs and grass but increase again in C. The most characteristic species in these transient zones is *Aiolopus,* which, in contrast to its cousin, *Locusta,* does not invade zone A.

Aphis and its predator, *Ischiodon,* were found in this zone on *Portulaca,* the dominant plant in C and D, although the former species was found in zone A as milk cows inside a nest of *Tetramorium. Solenopsis* was also found only in this zone.

With the further decrease of plant cover, animals adapted to bare surfaces appeared in D. The characteristic species was *Oligotoma,* which was extremely abundant in runways and adjacent exposed areas, dwelling in a characteristic nest spun by themselves (Fig. 16). If they were driven away from the nest, they were hunted by *Lasius* as soon as they were discovered by this ant. At night, winged adults were collected around the lamps situated near the runway.

Zones C′ and D′ are reproductions of C and D in the littoral zone. A characteristic animal assemblage was collected under the stones and large gravels in C'_1: it consisted of *Geogarypus,* an oribatid mite, two collembola, myriapods, etc. On exposed surfaces, however, there were very few animals, except for *Lasius* and *Tapinoma* walking on the runners of *Ipomoea.* D′, especially, was macroscopically a complete abiotic zone. The only animals collected were *Anisolabis,* found under the decayed matter. Although it did not belong to the land biota, an endemic marine collembola, *Polyacanthella oceanica* Uchida, was discovered at the northern rocky reef of the NW. shore, together with some polychaetes, crabs, etc. According to a

staff member of the weather station, a marine strider seems to occur in the lagoon.

The area receiving direct human influences possesses no more than a well-known assemblage of domestic species. The number of species is far less than that found in similar environments on continents, but, reflecting the diversity of environmental conditions, it is fairly large in comparison with other habitats, in spite of the small space. A rat, two roaches, some domestic flies as omnivorous scavengers, two granary beetles, and domestic silver fish, *Ctenolepisma,* were the chief members in or around the weather station and accompanying buildings. Skinks, land crabs, and the two ants invaded all buildings. Gecko and *Heteropoda* lived there as residential predators, although they were found in the A zone, too. Earthen nests of *Sceliphron* were abundant on ceilings, walls, and other parts of buildings. In a ruined cottage standing near the northern point of the island, a fairly large compound nest containing 62 cells was observed attached to a broken chimney (Fig. 17). In other nests, the number of cells counted was as follows: 1 cell alone (1 instance), 2 cells (3 instances), 3 (4), 6 (3), 7 (1), 8 (1), 12 (3), 14 (1), 30 (1), 57 (1).

Numerous dead insects were observed in window screens of the dining room, etc., due to treatment with DDT. Examination of these accumulations showed an overwhelming abundance of *Atherigona,* although the main species found within the dining room during our stay were *Musca, Lucilia,* and *Sarcophaga.*

SPECIES	INDIVIDUAL NUMBER (Sexes not separately counted)
Atherigona excisa	1,505
Drosophila melanogaster	43
Lucilia sericata	22
Aneurina sp.	22
Dolichopodidae gen. sp.	18
Parasarcophaga misera	16
Agromyzidae gen. sp.	13
Sphaeroceridae gen. sp.	10
Musca domestica	4
Tribolium castaneum	3
Ephydridae gen. sp.	2
Gardiastethus fulvescens	1
Lasius niger ssp.	1
A micro-moth	1

All of the moths listed in Table 3, as well as *Oligotoma* and *Eobia,* were attracted to lamps. Because of its oedemogenic secretion, *Eobia* is the only insect species injurious to human beings. No fleas, mosquitoes, or blackflies occur on the island.

After this brief sketch of the different habitats, a mystifying fact must be mentioned: a dragonfly, *Diplacodes bipunctata,* occurred on the island, even in the absence of fresh water. The adults of this species appeared a considerable time after our visit. I observed only a single specimen, at a passway penetrating the E. triangle, but a staff member of the weather station repeatedly confirmed the appearance of numerous dragonflies, and later he kindly sent me the specimen which was identified. If this species multiplies on the island, then not only must fresh water be available somewhere but also a number of aquatic organisms to be preyed upon by its nymphs. In the absence of any evidence of fresh water, the only other explanation must be the seasonal migration of this relatively delicate species across thousands of kilometers of ocean—although this is an explanation that I myself find hard to believe.

FURTHER ECOLOGICAL NOTES

Ecological interactions among various organisms in a given area, however few there may be, are always difficult to demonstrate clearly. But, the uncomplicated environment and simple biota of Marcus permit schematizing it as in Figure 18. Even if the schema is still far from complete in many points, the principal courses of biotic energy-flow in the island are obvious and may be classified into two major groups with respect to the energy sources: those starting from green plants, and those from the products of human activities. The two groups are relatively independent of each other, although, as discussed later, many elements constituting the former group were brought to the island by various human activities. As a glance at the figure will show, the extreme disharmony between the food chains and the occurrence of numerous unoccupied niches is impressive. The extraordinary abundance of a few dominant species depends, without doubt, on this too

simple bio-economic structure. Such disharmony, a common feature of remote oceanic islands, is also recognized by comparing the number of genera and species occurring upon the island. Except for birds, the total number of families, genera, and species of land animals is 54, 70, and 72, respectively. Only seven families contain more than two species: the Blattidae (5 spp.); Formicidae (4 spp.); Porcellidae, Entomophyridae, Lygaeidae, Noctuidae, and Muscidae (2). There are only two genera containing two species: *Periplaneta* and *Porcellio.*

In connection with this disharmony, it may be interesting to consider here the association of closely related species, for it has often attracted the attention of ecologists on account of competition or isolation. However, most species belonging to families represented by more than two species show obvious habitat-segregation. Species found in one and the same habitat were *Leucophanea* and *Blatta, Anisolabis* and *Euborella* in A_1 and D; two species of *Periplaneta, Lucilia,* and *Musca* in H; two *Porcellio* in A_1; *Sira* and *Lepidocyrtus* in C'_1; *Lasius* and *Tapinoma* almost everywhere. But, most of them differ from each other either in habit, as in the two ants mentioned above, or in their relative abundance in various habitats. Those species possessing similar habits, eating similar food, and collected from the same habitat were only two pairs of cosmo- or tropicopolitan species, *Musca* and *Lucilia,* and two *Periplaneta.*

In former times, the island offered a favorable breeding site for various sea birds. Subsequent reckless catching resulted in a rapid decrease of both the species and numbers of individuals. During our visit, two species, noddy terns and sooty terns, still bred on the island. Moreover, about 20 golden plovers and five American wandering tattlers were seen. Of these birds, only the plovers may have an intimate relation to the land biota. They were seen usually on the surface of the runway or on other roads through the E. triangle. According to Kuroda (in litt.), some vegetable matter was found in their crops. On the other hand, he did not find any food other than cuttlefish in the crops of the terns. Therefore, terns and tattlers are connected intimately to the marine ecosystem but possess little relation to land biota.

Finally, some phenological trends are cited here, based upon the experience of the weather station staff (especially of Messrs. Y. Nakada and K. Fujisawa), as follows: Fructification of papaya, September to October; flowering of *Ipomoea,* April, and September to October; flowering of *Messerschmidia,* March to August; nymphs of *Locusta,* seen throughout the year, but abundant during July and August; *Diplacodes* adults, June to July, and September to October; larvae of *Herse,* throughout year, but

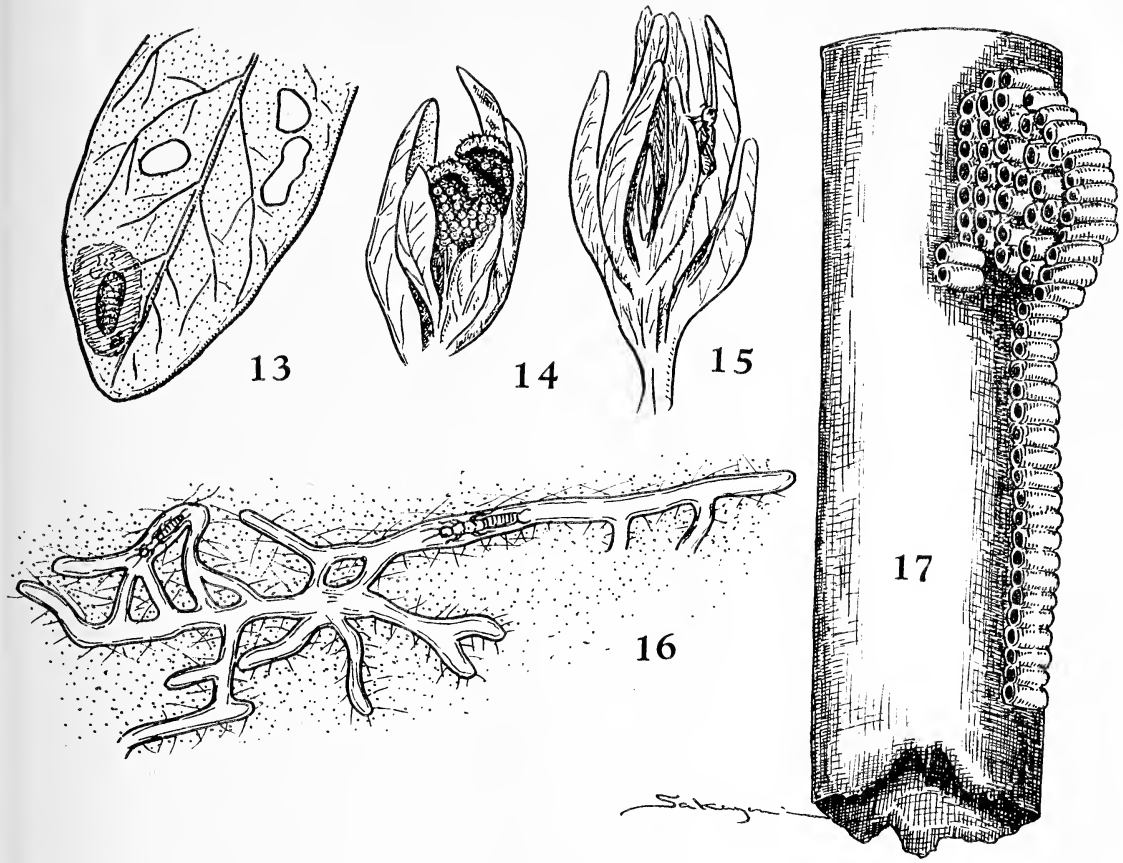
TABLE 4

NUMBER OF SPECIES FOUND IN EACH HABITAT
(Those in parentheses were found exclusively in that habitat.)

VERTICAL DISTRIBUTION	HORIZONTAL DISTRIBUTION							TOTAL
	A	B	C	D	C′	D′	H	
1	27(15)	13(0)	19(1)	20(4)	10(3)	1(0)		45(35
2	14(0)	7(0)	10(0)		3(0)			29(9)
3	20(3)	9(2)						
Total	47(19)	21(2)	23(1)	20(4)	10(3)	1(0)		

Order of richness in number of species: $A_1 \gg D = A_3 \geq C_1 > A_2 \geq B_1 > C_1' = C_2 \geq B_3 \geq B_2 > C_2' > D'$

Order of ecological endemicity: $A_1 \gg D \geq A_3 = C_1' \geq B_3 \geq C_1 > A_2 = B_1 = C_2 = B_2 = C_2' = D'$



FIGS. 13–17. Some aspects of insect life on Marcus. Explanation in text.

abundant in June; assemblage of *Eobia* in lamps, May to June, and August to October.

These data are still insufficient but indicate the monotonous and inconspicuous phenological trends on this island. This may be also recognized from the occurrence of all developmental stages of *Locusta, Landreva,* and *Utetheisa* during our short stay.

BIOGEOGRAPHICAL REMARKS

Marcus is of little interest from the point of view of regional biogeography. According to Tuyama, who not only identified all plants collected by me but also kindly informed me of their distribution and ecological characteristics, all the plants are species of wide distribution and high vigor. After comparing the very simple flora of Marcus Island with that of the Bonin Islands—where 46 per cent of a total of 321 species are endemic, and where five endemic genera are found (Nakai, 1930)—it is probably futile to discuss the phytogeographical position of Marcus.

The same conclusion can be applied to land animals. According to Gressitt (1956), the island belongs by its location to the Oriental Zoogeographical Region, Polynesian Subregion, Division Polynesia Proper, and Subdivision Micronesia. But the order of frequency of the various distributional patterns is: Tropicopolitans (including Indo-Pacificopolitans) (18 spp.); Cosmopolitans (13); Pacificopolitans (6); Pan-Palaearctic (5); Endemic (4); Species with a

limited range (4). Distinction of these patterns is rather arbitrary but may be sufficient to conclude that most of the species belong to types which can hardly be said to be the regional, although in general the Oriental elements are predominant.

It is remarkable that four endemic terrestrial species, one centipede and three pseudo-scorpions, were discovered upon this tiny island. One of the latter group, *Lechytia sakagamii* Morikawa, is very interesting because it belongs to a genus which, up to the present time, has been recorded only from Nearctic, Neotropical, and Ethiopean regions (Morikawa, 1952).

FORMATION OF LAND BIOTA

The land biota described above has been compared to the earlier results published by Yabe (1902), Yoshida (1902), Bryan (1903), and Tuyama (1938). The plant species reported by those writers and by me are given synoptically in Table 2. From this table and from information kindly given me by Mr. Matsubara, the commander of Japanese Marcus Garrison during World War II, we can trace the floristic change of the island during the last 50 years.

With respect to trees and shrubs, only *Cocos* and *Messerschmidia* have continued to exist throughout half a century. This combination, one of the commonest edaphic climaxes on sandy beaches of the Pacific islands, in all probability had been already well established when the island was discovered. Later, but before 1938, the island received *Pisonia* as a new member of its flora, and it is now a chief member of the vegetation. On the other hand, *Morinda* disappeared between 1938 and 1940, because this was reported by Tuyama but not by Matsubara. Although still surviving at the present time, the coconut palms received remarkable damage from human interference (cf. Appendix). When Bryan visited the island in 1903, palms grew densely in the central area of about 3 acres. According to Matsubara, there were only 30 trees, about 4.5 m. high, when he arrived upon the island in 1941. Half of them were cut down at the end of that year. Moreover, as seen from the Appendix, all trees on the island were completely damaged by repeated bombing during the war. The present arboreal stratum is, therefore, the outcome of postwar regeneration.

The origin of papaya now existing in the island is obscure. Bryan gave seeds of various plants, including papayas, to the Japanese inhabitants when he left the island. Later Tuyama reported this plant from the island. But no papaya trees were growing in 1941 according to Matsubara. He planted a few seeds in 1945, and some seedlings grew to the height of a child before being damaged by bombing. The plants now growing in the island seem to have been brought in by the U. S. Navy after the war.

Of the herbs and grasses, tobacco and *Portulacea* are the only species reported by all writers, including myself. Judging from the small size and simple topography of the island, which permit one to walk around it within 2 hours, it is hard to believe that any abundant plant species escaped the eyes of other collectors.[6] Therefore, the lack of accord among four collections suggests the unstable character of the herbaceous strata, with new inhabitants appearing and being replaced in their turn by other ones, under the influence of human activities during the last 50 years. *Ipomoea* was first reported in 1938, but Matsubara wrote me that in 1943 it was found only in scattered patches on the island. The overwhelming dominance of this species throughout the island at the present time is, therefore, a postwar event.

Previous information concerning land animals is scanty. The most important change may be the extinction of numerous sea birds which bred on the island. A catastrophic decrease may well be recognized if the report of Bryan (1903) is compared with that of Kuroda (1953).

With respect to other land species, Yoshida (1902) briefly described a skink, gecko, "flies," "red moths," and "small flies." Bryan also reported a skink (*Ablepharus boutonii*) and a gecko (*Perochirus articulatus*). Therefore, both have been constant inhabitants during 50 years, although their scientific names have been changed since Yoshida's visit. Among three land crabs mentioned by him—*Grapsus grap-*

[6] Actually, except for *Bryophyllum,* all of the plant species collected by me were discovered on the first day of our survey.

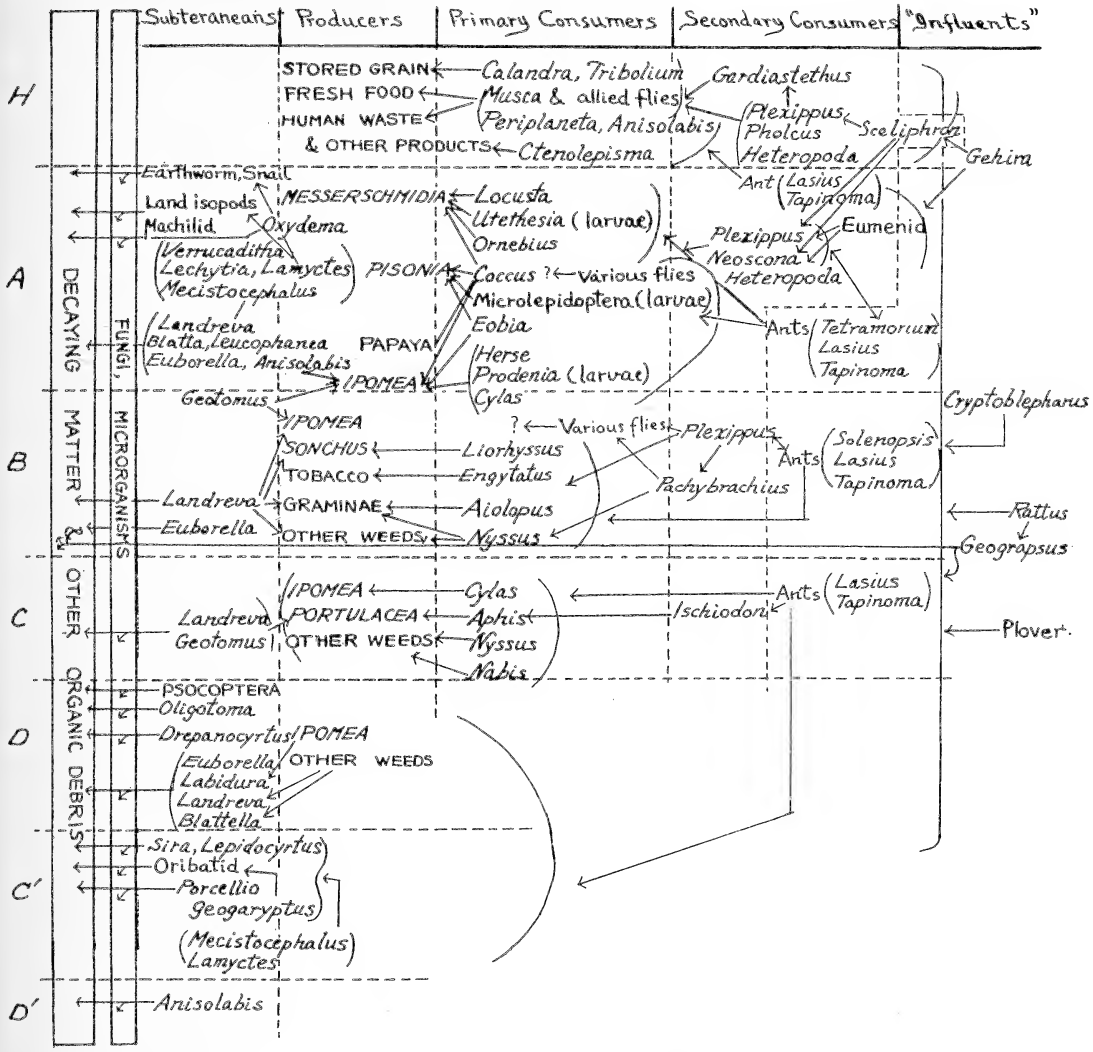


FIG. 18. Food-nexuses in Marcus Island.

sus (abundant), *Geograpsus crisipes* (less abundant), and *G. grayi* (abundant)—only the last species still remains on the island. According to a personal communication from a staff member of the weather station, he is sure that at least one species of land hermit crab still exists on the island. But it is uncertain whether this species is either *Coenobita olivieri* or *C. compressa* reported by Bryan, for no specimens were collected by myself.

It is very regrettable that Bryan's collection of insects, which he made by various methods (including lantern collecting, barking, attracting with decaying flesh, etc.) was damaged by ants and other pests during his return voyage. His miscellaneous notes based upon memory are so interesting, however, that I will cite them here:

A small red ant was quite common as well as troublesome, especially about the settlements. I fancy it had been imported since the colony was established. Two species of flies were very abundant, one a blowfly (*Calliphora*?) which persisted in laying its eggs on the birds both before and after they were skinned; the other species, a small vinegar fly of a genus unfamiliar to me,

...were to be seen in moist, shady places all over the island. A small miller was common during the night, and I am of the opinion that the skinks and geckos feed on it as well as on the small flies just mentioned....

The only spider that had established itself was the widely distributed web-spinning species, *Epeira nautica*.... Trees and grass showed little or no signs of insect pests. In fact, I found only one species of plant that had been molested by biting insects. Since these depredations were to be seen only in a very limited area, and as I was unable to secure the miscreant either by day or night, I concluded the species must have been a recent Japanese introduction that had not had time to thoroughly establish itself. No species of Coleoptera were secured [pp. 117–8].

No land shells were noted, and I believe there were none [p. 120].

Believing that a collection of any earthworms that might occur on the island would be of interest I requested Mr. Sedgwick and his assistants to keep a close lookout for them. Although they made a large number of excavations in various places while prosecuting their investigations, they were unable to discover a single specimen.... I am persuaded that worms of this class have not as yet found their way thither [p. 122].

Compare these citations with results obtained by me, and remember that both surveys were made approximately in the same season and during the same interval (cf. Appendix, 1902). It may be assumed that, in all probability, many species now inhabiting the island were established there after 1902.

Only *Neoscona theisi* (Walckenaer) (=*Epeira nautica* Bryan nec Koch) and, seemingly, some domestic dipterans are the inhabitants collected in both surveys. It is not certain whether Bryan's "red, small ant" corresponds to any of four ant species collected by me or not. But it surely differs from *Lasius niger,* the commonest ant in 1952.

Consequently, judging from their conspicuousness and present abundance, the following species may safely be regarded as immigrants since 1902:

Plexippus paykulli
Heteropoda venatoria
Periplaneta americana
Prodenia litura
Herse convolvuli
Sceliphron caementarium
P. australasiae
Landreva clara
Locusta migratoria
? *Allolobophora* sp.
A land snail
Lasius niger
Calandra oryzae
Cylas formicarium
Tribolium castaneum
Eobia chinensis

Although with less certainty, the following species are also assumed to be relatively recent immigrants:

Armadillo sp.
Ctenolepisma villosa
Euborella annulipes
Anisolabis martima
Aiolopus tamulus
Oligotoma saundersi

It is uncertain whether or not a "red moth" mentioned by Yoshida corresponds to *Utetheisa.* But, from Bryan's notes, it is highly probable that the number of individuals was very small, even if this species was present in 1902.

Matsubara wrote me only about the skink, gecko, land crab, flies, and cricket as being the impressive animals during his wartime service. From these accounts, we can assume that *Landreva* was established before 1943. On the other hand, *Locusta, Eiobia,* and *Periplaneta* must have arrived after World War II, for these animals, if they occurred, certainly would have attracted the attention even of persons not biologically observant, either by their conspicuousness (as in *Locusta*) or by their sanitary importance. Needless to repeat, the species now most abundant are, in general, the relatively recent immigrants.

Thus, most members of the land biota of Marcus are immigrants since 1902. Considering the extremely isolated location of the island, it must be obvious that most of these species gained their chances to arrive on the island and to establish themselves there only through direct and indirect human interference at the island. My conclusion, therefore, is that the present land biota is, in its origin, largely an outcome of human activities directed upon the island.

CONCLUDING REMARKS AND GENERAL CONSIDERATIONS

In connection with the zoogeography of Pacific islands, Gressitt (1956) gave an appropriate summary on the nature of land fauna in

low coral islands: "Atolls and other low coral islands have a small fauna—similar in widely separated groups of islands—which is limited by the lack of ecological diversity, the limited haplophytic strand flora, the presence of brackish ground-water, the scarcity of soil, and exposure to salt-spray."

The land biota of Marcus, with its extreme poverty in both taxonomic and ecological components, offers nothing other than a very typical example of Gressitt's generalization. He also wrote: "The extent of speciation is directly related to the island's age, size, isolation and diversity of environment." This proposition can be applied to biocoenology if the word "speciation" is replaced by the phrase "differentiation of ecological components." On Marcus Island the isolation is fairly great, but its size and its diversity of environment are incomparably small to be able to promote any ecological differentiation. Moreover, this isolation may modify a given biota only when human interference is absent or at least negligible, because this factor acts, however locally, with an incomparably more rapid tempo and more violent means than do other natural agents. It would be rather surprising if Marcus Island had maintained any ecological peculiarities—even if such had existed in this most simple environment—despite the accumulation of various human interference during 50 years, including intensive skinning, coconut collecting, public works which modified the appearance of the island, a high human population during wartime (when 4,000 persons were living on this mere heap of coral sand and pebbles), and, finally, violent bombing.

However, although Marcus Island may be little more than a disappointment to biologists who approach the island to study its flora or its biogeography, investigation of such an undifferentiated biota does reveal some important problems, as follows:

1. Our knowledge of the ecology of Pacific islands, as mentioned by Gressitt (1954), is still very far from complete. In this account, the study of a relatively simple biota as that of Marcus may serve as a useful guide either to study more complex biotas or to find general principles underlying their diversities.

2. Considering the fact that any given ecological assemblages, either simple or complex, consist of interactions among numerous parts and processes, it is obvious that the analysis of such entities is far easier to do in simpler biota than in more complicated ones. It should be remembered that, while we may be interested in discovering any specificities and comparing them with each other, we must always seek general rules governing such specificities.

3. Because of their extreme isolation, ecological simplicity, and lack of industrial importance, the remote low islands such as Marcus may serve as the best laboratories in field ecology for the study of the intra- and interspecific ecology of given species, both native and purposely introduced, as living isotopes. The clarification of land biota should be a prerequisite for such experimental studies.

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The survey was made with the permission of Dr. S. Wadachi, Head of Central Meteorological Observatory in Tokyo, aided by numerous staff members of the Observatory, especially Mr. N. Yamada, Chief Secretary, Mr. Y. Nakada, Head of the Remote Islands Section, Mr. T. Doi, Head of the Supply Section, Mr. H. Hasegawa of the Entomological Laboratory, the National Institute of Agricultural Sciences, Tokyo, and Mr. H. Okuyama, Botanical Laboratory of the National Science Museum, Tokyo.

The specimens collected by me were identified by the following gentlemen, who also gave me valuable information on the distribution and habits of the species collected: Mr. T. Aoto (Reptilia), Dr. S. Asahina (Odonata), Mr. S. Ehara (Acari), the late Dr. T. Esaki (Embioptera), Mr. H. Hasegawa (Heteroptera), Mr. K. Hori (Muscidae and Sarcophagidae), Dr. A. Kawada (moths), Mr. S. Kato (Anthomyidae), Mr. M. Konishi (Cossoninae), Mr. K. Kosugi (Coleoptera), Mr. Y. Miyoshi (Myriapoda),

Mr. K. Morikawa (Cheriferidea), Mr. M. Moritsu (Aphidae), Dr. T. Nakane (Coleoptera), Mr. N. Nozawa (Orthopteroidea), Mr. H. Nishijima (Diptera), Dr. S. Saito (Araneae), Dr. T. Sakai (land crabs), Dr. T. Shiraki (Orthopteroidea), Dr. R. Takahashi (Coccidae), Dr. K. Tsuneki (ants), Dr. H. Uchida (Apterygota), Mr. T. Yaginuma (Araneae), Dr. E. Yamaguchi (Oligochaeta), and Dr. T. Tuyama (plants).

Some names have been added or changed on the basis of studies done upon the insects of Micronesia by J. C. M. Carvalho, H. G. Barber, and H. de Souza Lopes not cited in my references.

Valuable information on the animals and plants during wartime was obtained from Mr. M. Matsubara, the commander of the Japanese garrison on Marcus Island during World War II. Messrs. Y. Nakada and K. Fujisawa of the Remote Islands Section of the Observatory gave me suggestions on the land biota. Dr. T. Kira of Osaka City University kindly answered my inquiries on the climatic and vegetational features of the island.

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I should like to express my sincere thanks to all of these gentlemen, whose help was indispensable in preparing the present paper.

SUMMARY

Based upon information obtained directly during the period from April 30 to May 6, 1952, and from previous works and personal communications, a general perspective of the land biota of Marcus Island in the western Pacific is outlined. As might be expected from the small size and lack of environmental diversity, the land biota shows the typical poor structure common to low reef islands of the Pacific. Most constituents of the biota seem to have been introduced during relatively recent years, probably aided by direct and indirect human activities upon the island.

APPENDIX

AN ANNOTATED HISTORY OF MARCUS ISLAND

As mentioned by Bryan, the discovery, naming, and early history of the island cannot be thoroughly traced in the obscurity of the chronicles from the last century. The following table was prepared from the accounts of Yoshida (1902), Bryan (1903), and Shiga (1903), and from personal communications from Mr. Matsubara and staff members of the weather station.

Before 1860: Some reports of Pacific whalers give some information on the island, but with much confusion about its name and location (Bryan).

1868: Captain Kilton, aboard the "David Hoadley," visited in May and described the place as a low sandy island covered with trees and bushes (Bryan). Discovered in this year by an American, and thereafter visited occasionally by French and British ships (Shiga).

1874: U. S. survey ship "Tuscarora" (Commander Belknap) visited. The Hawaiian Mission ship "Morning Star" (Captain Gelett) visited and reported a dense cover of trees and shrubbery, with a white sandy beach (Bryan). Tsunetarô Shinzaki visited as a passenger in a British ship (Yoshida). This was the first visit by a Japanese (Shiga).

1889: Captain Rosehill landed in June while engaged in trading in the Pacific. He recognized the island's value as a source of coconuts. Believing himself to be the discoverer, he claimed it for the United States (Bryan, Yoshida).

1896: A stone lantern (Ishi-dôrô), with an inscription of February 12, 1896, written in Japanese, existed on the island until its destruction by U. S. bombers during World War II (Matsubara). Shinroku Mizutani, Chief of the South Sea Section, Tokyo Animal Company (Tokyo Kinjû Gaisha), while he was a sailor aboard the "Tenyû-maru," was cast ashore in a storm (Yoshida, Matsubara).

1898: In July, the Tokyo Prefectural Office claimed the island as a Japanese dependency, named it Minami-Torishima (South Bird Island), and incorporated it into the Ogasawara Section (the Bonins) of Tokyo Prefecture (Yoshida). In September, tenanting the island from the Tokyo Prefectural Office, Shinroku Mizutani began the skinning of sea birds, aided by the investment of Shichigorô Kamitaki, a trader in Yokohama (Yoshida). Haruzo Ogawa, a lieutenant in the second reserve of the Japanese Navy, called the inhabitants of Hachijôzima and of the Bonins to Marcus Island for help in skinning the sea birds (Matsubara).

1899–1902: According to grave posts (now missing), three Japanese died in the island during these years (Matsubara).

1901: In October a violent typhoon attacked the island for 10 days, sending the sea as far as 22 ft. above the normal level (Bryan).

1902: Hearing of Captain Rosehill's expedition (see below), the Japanese Government sent the cruiser "Kasagi" to the island. Akiyuki Toyoguchi, a sub-lieutenant, landed with 15 men (July 27). Captain Rosehill arrived at the island on July 30, accompanied by Dr. Bryan and Mr. Sedgwick, in order to claim it as a U. S. territory, but left on August 5 because of its occupation by the Japanese Navy. Bryan and Sedgwick made a scientific survey of the island during the 5 days. August 28, the Japanese Government sent another cruiser, the "Takachiho." S. Kamitaki (a trader mentioned above), S. Shiga, M. P., and O. Yoshida, a geologist, landed. Two Japanese shrines, *Kotohira* and *Ohtori,* were built there ("Tengaisei"). September 2, a typhoon passed over the island. All inhabitants sought safety at the highest point. Until December 25, no food other than birds and fish was available. Sixteen died during this period (Nakada). In September, the Japanese Department of Foreign Affairs again claimed the island for Japan. The following publications appeared: Plants of Marcus (Yabe), Miscellaneous notes on the geology and topography (Yoshida), Chronicle of a journey to the island ("Tengaisei").

1903: Shiga published an essay describing the discovery of this island. He asserted its importance from the national standpoint. Bryan's comprehensive monograph was published. Han-emon Tamaoki, a Japanese, went to the island to collect coconuts but left without success (Matsubara).

1906–16: Many Japanese were landed for phosphate mining. Nineteen died during these years (Matsubara).

1930: In November, all 32 inhabitants, who had been engaged in coconut collecting and fishing, left the island (Matsubara).

1931: The island was purchased by the Japanese Navy (Matsubara).

1935: The Hydrographical Department of the Japanese Navy began meteorological observations (Matsubara).

1937: Establishment of the Japanese Navy airport commenced (Matsubara).

1938: Tuyama published his Flora of Marcus Island.

1939: February 22, a large flock of terns visited the island. March 15–16, a large flock of "swallows" passed through. Terns and swallows appeared also in autumn (Matsubara).

1941: The island was armed with six 15 cm. cannons and six 8 cm. aeroguns (Matsubara). Japan declared war upon the United States.

1942: March 4, the island was bombed by 40 U. S. carrier-based planes (Matsubara).

1943: A garrison consisting of 1,100 navy, 2,250 army, and 650 civilian personnel was installed with M. Matsubara as commander.

1944: May 20–21, bombed by 132 U. S. carrier-based planes. October 9, bombarded by a U. S. naval squadron consisting of one battleship (Pennsylvania type), two heavy cruisers (Pensacola type), and five large destroyers (Matsubara).

1945: Received 171 attacks by a total of 759 bombers from September, 1944, to the armistice on August 15, 1945. October 7, the Japanese garrison left the island (Ma-

tsubara). November, occupied by U. S. Navy (Weather Station).

1946: U. S. Navy left the island because of the great damage to the establishment by typhoon Martha (Weather Station).

1950: The Central Meteorological Observatory in Tokyo made a survey in order to re-establish the runway and weather station on the island (Weather Station).

1951: Meteorological observations began again on the island (Weather Station).

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Two New Species of Chaetognatha from the Waters off Peru

PAUL N. SUND[1]

SINCE FEBRUARY, 1958, the Consejo de Investigaciones Hidrobiológicas of Peru has been making regular cruises to investigate the biological and hydrographic conditions off the coast of Peru. Through the kindness of Dr. Z. Popovici, I have been able to examine the Chaetognatha from plankton tows taken in the course of these investigations. The tows were made at the surface, using ½-meter nets.

The first specimens of the two new species reported were noted in a plankton sample taken on March 5, 1958, near the entrance to the Port of Talara, Peru. Inspection of other samples taken during the expedition (cruise 5802) revealed numerous individuals of one of the new species, *Sagitta peruviana*; but none of the second species, *Sagitta popovicii,* was noted (Fig. 1). The descriptions of the new species are based on specimens preserved in formalin.

[1] Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography, La Jolla, California. Manuscript received April 29, 1960.

Sagitta peruviana n. sp.
Fig. 2*A–L*

Holotype, 1 specimen, USNM no. 29921
Paratypes, 10 specimens, USNM no. 29922

Body rigid, opaque, hispid. Tail segment 23–29 per cent of total length. Anterior fins completely rayed, start at posterior end of ventral ganglion. Posterior fins separate from anterior fins, completely rayed, reach posteriorly to seminal vesicles; greatest portion on tail segment, widest behind tail septum, about same length as anterior fins, posterolateral margin somewhat concave. Caudal fin triangular with rounded lateral apices; in contact with seminal vesicles. Anterior teeth 4–9; posterior teeth 10–21; hooks 7–9. Seminal vesicles, when mature, with expanded anterolateral corner. Ovaries may extend to neck; ovaries with ova not filling body cavity, ova in two dorsoventrally placed rows. Collarette conspicuous, extends posteriorly to approximately ½ distance between head and ventral ganglion. Corona ciliata extends from between eyes to about ⅔ distance from head to ventral ganglion. Intestinal diverticula absent. Eye pigment dense, apparent shape quadrangular, with elongate extension arising medially from center of median side of pigmented area.

BODY LENGTH IN MM.	TAIL SEGMENT % TOTAL	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH	MATURITY STAGE	LENGTH OF OVARY IN MM.
13.2	24.0	8	9	21	IV	7.1
12.8	24.2	8	9	19–21	II–III	2.1
11.9	24.4	7	9	15–18	I(?)	1.1
11.4	24.5	7	—	17–18	III	1.3
11.3	25.7	8	—	—	III–IV	4.1
10.9	25.7	8	8	20	III	4.1
10.5	25.7	7	—	—	II–III	1.2
10.4	24.0–25.0	7–8	7–8	16	III–IV	2.5–2.7
10.1	25.7	8	6	19	III	2.9
9.8	23.0	8	6	12	III–IV	3.0
9.1	24.2	7	5	13	III	2.7
8.4	25.0	8	8	15	Juv.	—
7.2	26.4	8	5	13	Juv.	—
6.8	25.0	8	5	12	Juv.	—
5.8	29.3	9	4–6	10–11	Juv.	—
5.3	26.4	8	4	10	Juv.	—

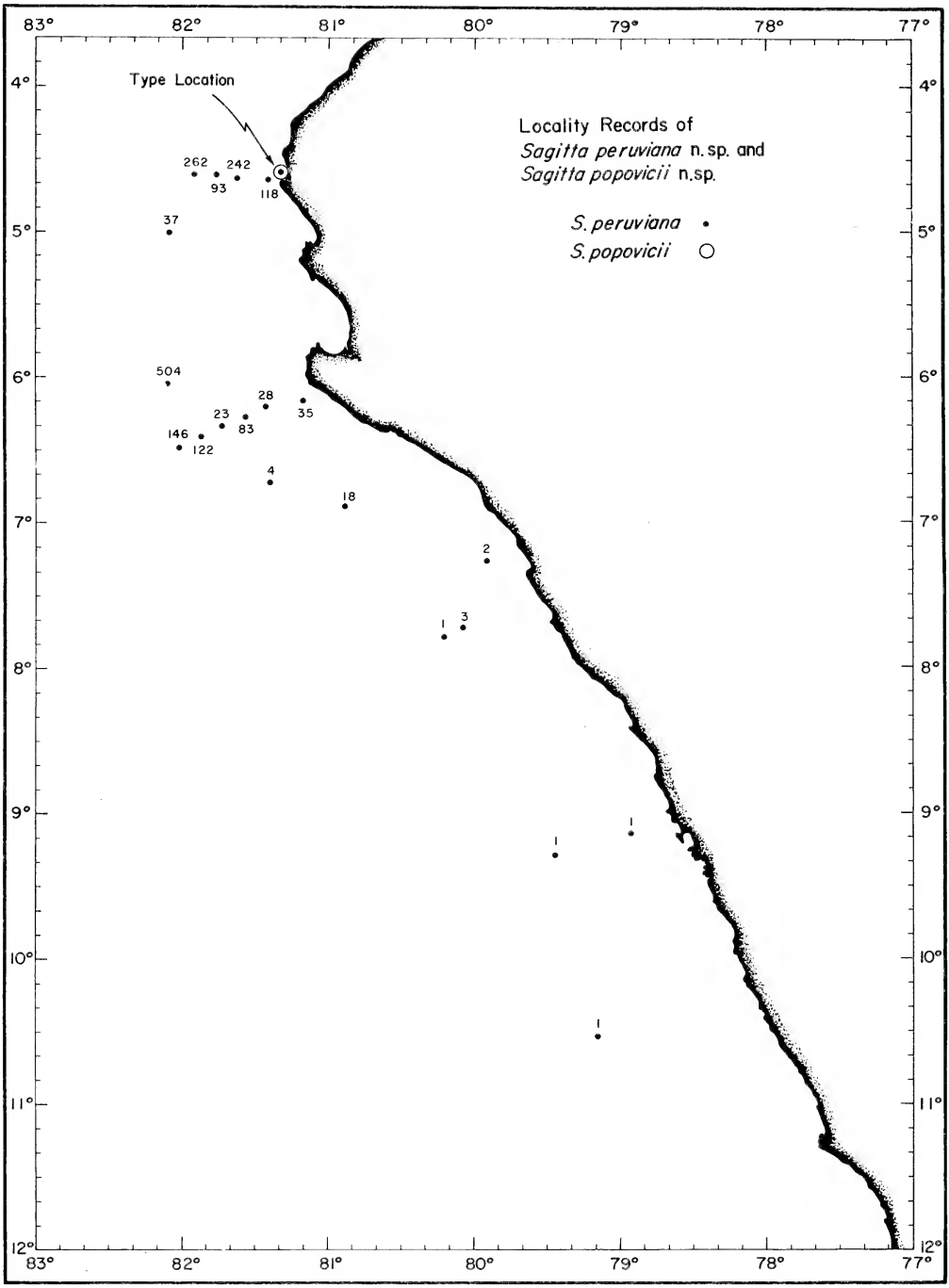

FIG. 1. Locality records of *S. peruviana* and *S. popovicii*. Figures indicate number of specimens present in sample.

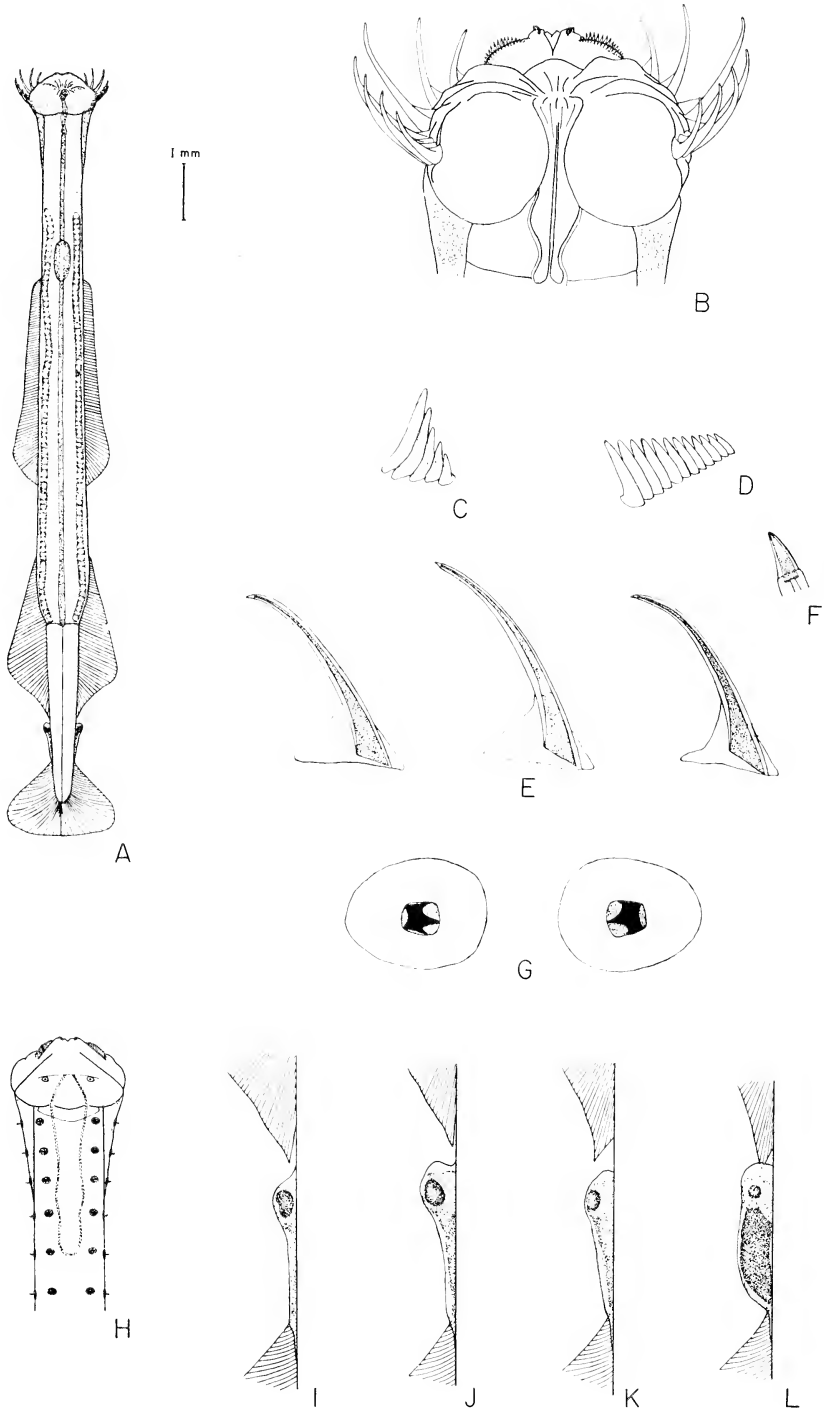

FIG. 2. *Sagitta peruviana* n. sp. *A*, Entire animal, ventral view; *B*, ventral view of head; *C*, anterior teeth; *D*, posterior teeth; *E*, typical hooks; *F*, detail of tip of hook; *G*, eyes, showing pigment distribution; *H*, dorsal view of anterior end of animal; *I–L*, stages of development of seminal vesicle.

FORMULA: The body form and general shape of the lateral fins is reminiscent of *S. bipunctata* Quoy et Gaimard 1827 and *S. hispida* Conant 1895. But the fact that the posterior and caudal fins of *S. peruviana* both are in such close proximity to the seminal vesicles distinguishes it from either of these two species.

The seminal vesicles in the later stages of development resemble those of *S. neglecta* Aida 1897 and *S. friderici* Ritter-Zahony 1911. Features that separate *S. peruviana* from *S. neglecta* and *S. friderici* are the robust body form, length of ovary, size of ova, shape of the lateral fins, and shape of the eye pigment.

The fact that the new species has no intestinal diverticula separates it from both *S. neglecta* and *S. hispida.*

Table 1 compares the features of the species discussed above.

Sagitta popovicii n. sp.

Fig. 3*A–F*

Holotype, 1 specimen, USNM no. 29923
Paratype, 1 specimen, USNM no. 29924

Body short, translucent, rigid; constriction at tail septum inconspicuous. Anterior fins start at posterior end of ventral ganglion, completely rayed, slightly tapered, widest near posterior end. Posterior fins separated from anterior fins by short but distinct interval, wider than anterior fins, widest posterior to septum, completely rayed, reach seminal vesicles. Caudal fin with rounded posterior margin, reaching seminal vesicle. Anterior teeth 3–4; posterior teeth 6–10; hooks 6–7. Seminal vesicle large, opaque, very conspicuous. Ovaries reach posterior region of anterior fins. Ova large, filling body cavity; up to 9 or 10 ova in a single row. Collarette present, small. Intestinal diverticula absent. Corona ciliata not observed. Pigmented area of eyes with an elongate extension arising from median side.

The above description is from four specimens, three of which were in such condition that the armature formulae and measurements could be determined. All four specimens were fully mature. The one specimen for which the measurements and formula were not made was found preserved in a distorted position.

FORMULA:

BODY LENGTH IN MM.	TAIL SEGMENT % TOTAL	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH	MATURITY STAGE	LENGTH OF OVARY IN MM.
5.8	32.8	7	3	6–7	IV	1.1
5.9 (2 indiv.)	26.3–28.6	6–7	3–4	9–10	IV	1.1

REMARKS: The present new species is similar in size and certain characteristics to *S. bedfordii* Doncaster 1903 (redescribed by Tokioka, 1942, and considered by him as synonymous with *S. pseudoregularis,* Tokioka, 1942 and 1952), *S.* sp. Tokioka 1954, and *S. pseudoregularis* Oye 1918. The differences and similarities are readily compared in tabular form. Inspection of Table 2 clearly illustrates that *S. popovicii* differs significantly enough from the other species to justify its designation as a new species. The name, *Sagitta popovicii,* is given in honor of Dr. Zacarias Popovici.

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FIG. 3. *Sagitta popovicii* n. sp. *A,* Entire animal, ventral view; *B,* eyes, showing pigment distribution; *C,* anterior teeth; *D,* posterior teeth; *E–F,* stages of development of seminal vesicle.

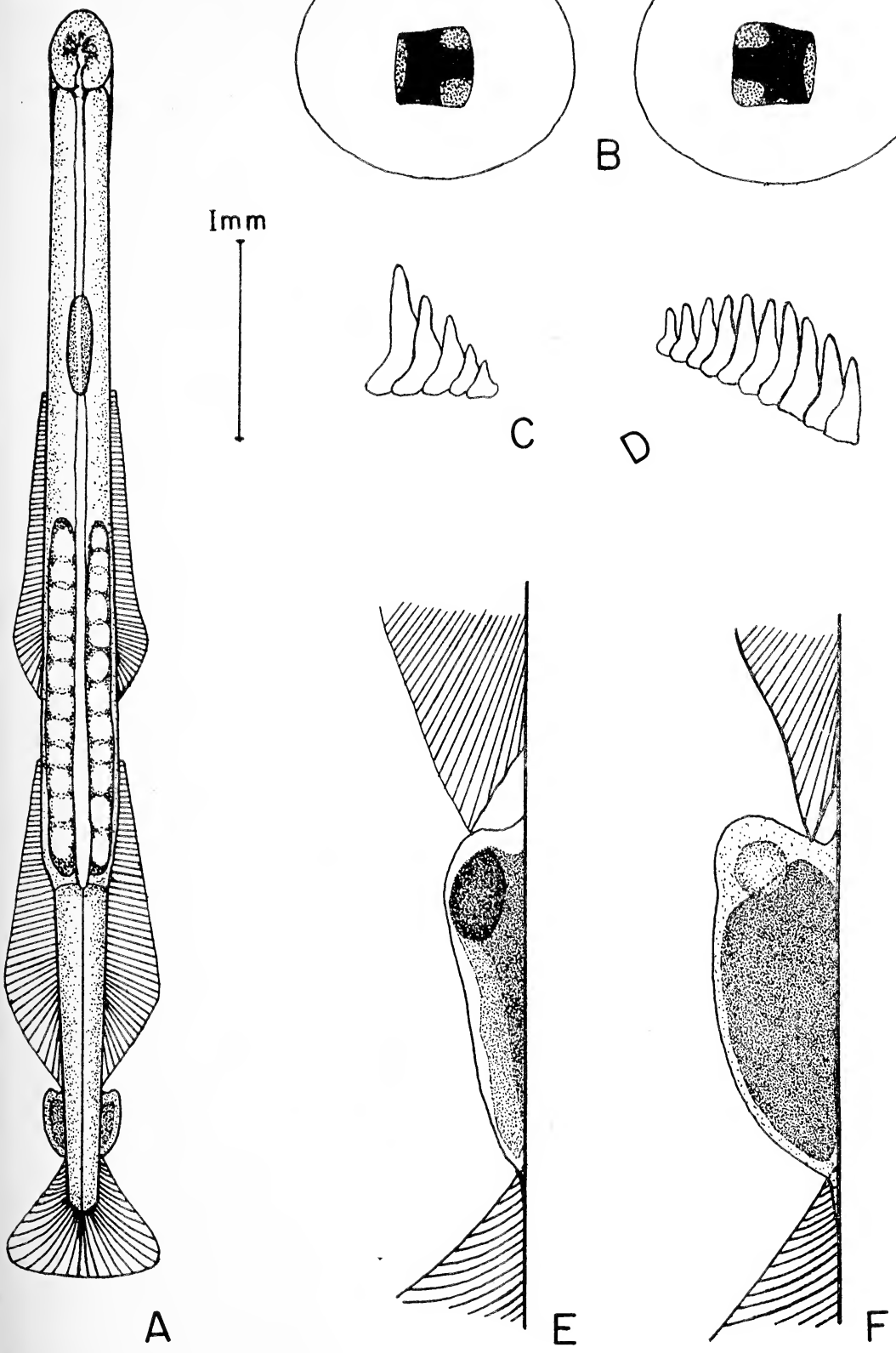
1mm
A
B
C
D
E
F

TABLE 1

	S. bipunctata	*S. hispida*	*S. neglecta*	*S. friderici*	*S. peruviana*
Body	Firm, opaque, length to ca. 12 mm.	7–11 mm. total length when mature. Hispid, numerous tactile prominences with sensory hairs.	Length to ca. 7 mm., firm, semi-opaque.	Strong, rigid, ca. 13 mm.	Rigid, opaque, hispid, length to ca. 13 mm.
Collarette	Present, conspicuous.	Conspicuous.	Present, not well developed.	Relatively narrow and short, reaching approximately ½ length corona.	Conspicuous, extends to ½ distance between head and ventral ganglion.
Anterior fins	Start at posterior end of ventral ganglion, completely rayed.	Long, rather slender, broadest in posterior part, extend near ventral ganglion level to posterior of center of total length.	Begin at posterior end of ventral ganglion. Semi-elliptical.	Completely rayed, narrow, broadening a little towards posterior, starting immediately behind the ventral ganglion.	Completely rayed, start at level of posterior end of ventral ganglion.
Posterior fins	Wider and slightly longer than anterior fins, do not reach seminal vesicles, widest behind tail septum, completely rayed.	Always broader than anterior; broadest in posterior part. Separated from anterior, situated more on caudal than on body segment.	Separate from anterior fins, longer, extending to middle of caudal segment. Semi-elliptical.	Completely rayed, only a little longer and broader than anterior, lying a little more on tail than on trunk, narrowed down in posteriormost part.	Separate from anterior, completely rayed, reach seminal vesicles, widest behind tail septum, posterolateral margin concave.
Corona ciliata	Extends from anterior to eyes to ⅔ the distance from head to ventral ganglion.	Extends from point anterior to eyes almost to level of ventral ganglion. Narrow and sinuous.	Long, like that of *S. bipunctata,* lies wholly on trunk.	2–3 times length of head, slightly indented, starting immediately behind brain.	Extends from between eyes to ⅔ distance from head to ventral ganglion.
Intestinal diverticula	Absent.	Present, well marked.	Present.	Absent.	Absent.
Tail segment, % total length	21–28	⅓ total length.	27–31	24–27 of total length.	23–29
No. hooks	5–10	8–9	6–8	Usually 8, seldom 9.	7–9
Anterior teeth	4–7	4–5	4–7	Up to 9, covering each other almost completely, brick-fashion.	4–9
Posterior teeth	8–14	8–14 or 15	10–17	Up to 22.	10–21
Ovary	Ovaries with ova not filling body cavity.	May extend beyond anterior extremity of anterior fins.	Reaches upper end of posterior fins.	Bulb-shaped, relatively short.	May extend to neck, ovaries with ova not filling body cavity; ova in 2 dorsoventrally placed rows.
Seminal vesicle	Separate from posterior fin, joined by caudal fin.	With cap as in *S. bipunctata;* divided by incomplete longitudinal septa.	Separate from caudal fin, in contact with posterior fins; large, rounded.	Elongate, with thickened anterior end, touching both posterior and caudal fins.	In contact with posterior and caudal fins; when mature, with expanded anterolateral corner.

TABLE 2

	S. bedfordii	*S.* sp.	*S. pseudoregularis*	*S. popovicii*, n. sp.
Body	Sturdy, opaque, uniform width; length ca. 3.5 mm.	Robust, opaque, uniform width; length ca. 4 mm.	Small, slender, not strong; length ca. 3 mm.	Short, rigid, translucent; length ca. 6 mm.
Collarette	Reaches level of posterior end of ventral ganglion.	"Practically absent," found very faintly around neck.	Voluminous, reaches to ventral ganglion; broadest at neck.	Small, but conspicuous, not reaching ventral ganglion.
Anterior fins	Begin at posterior end of ventral ganglion, completely rayed.	Begin at posterior end of ventral ganglion, completely rayed.	Very small, often inconspicuous, sparsely rayed, removed from ventral ganglion by ¼ distance ventral ganglion to septum.	Begin at posterior end of ventral ganglion, completely rayed, slightly tapered, widest near posterior end.
Posterior fins	About 2× length of anterior fin; more on tail than on trunk, widest behind tail septum, completely rayed.	½ as long as anterior fin, lie more on tail than on trunk, broadest behind septum, completely rayed.	Wide, rounded, with rays except at anterior and posterior ends, about ⅔ on tail.	Wider than anterior fin, widest posterior to septum, completely rayed, reaching seminal vesicle.
Corona ciliata	Short, elliptical, with slight depression on each side, begins at anterior end of trunk and stretches posteriorly to middle of distance between neck and ventral ganglion.	Type C, from behind eyes stretching on trunk nearly ½ length of head; depressions on each side.	Short, limited to head.	Not observed.
Intestinal diverticula	Very conspicuous.	Distinct.	Present.	Absent.
Tail segment, % total length	34–38	34.9	30–38	26–33
Number hooks	9–12	10	10–12	6–7
Anterior teeth	2–3, longer than posterior teeth.	4	2–3, long, sharp-pointed.	3–4
Posterior teeth	1–3	5	1–3, smaller than anterior teeth, overlapping.	6–10
Ovary	Reaches ventral ganglion, large ova, usually 10.	Immature.	Rod-shaped, reaching to ½ distance between ventral ganglion and septum.	Reaches posterior region of anterior fin. Ova large, fill body cavity, to 9–10 in a single row.
Seminal vesicle	Near posterior fin, apart from caudal fin. Similar to that of *S. regularis*.	Immature.	Elongate, becoming thicker posterior to anterior, approaching posterior fin, separated from caudal fin by ½ its length.	Large, opaque, in contact with caudal fin, near posterior fin. Of *"S. bedoti"* type.

A New Opisthobranch Mollusc from Hawaii

ALISON KAY[1]

THE OPISTHOBRANCH genus *Arthressa* was proposed by Evans (1950) on the basis of a revision of the genus *Volvatella* Pease 1860. Pease's genus was known only from four species, three described by Pease (1860, 1868), based on single specimens from the Pacific, and a fourth described by G. and H. Nevill (1869) from Ceylon. Evans (1950) pointed out several discrepancies in Pease's species descriptions, and, while retaining *V. fragilis* Pease, the type species, he proposed the genus *Arthressa* to include *A. cincta* (G. and H. Nevill) from Ceylon and *A. elioti* Evans which was newly described from Zanzibar.

Four specimens of a species congeneric but distinct from *A. cincta* and *A. elioti* have been collected in the Hawaiian Islands, and are here described as a new species.

GENUS *Arthressa* Evans 1950

SHELL: Thin, calcareous, covered by a thicker periostracum extending beyond the calcareous margin. Body whorl ovate, broadest in the middle, and contracting posteriorly to a spout. Anterior aperture as broad as shell in its anterior half. Right lip overlapping reflected left lip behind aperture; left lip depressed behind margin and passing at the junction of right and left lips under recurved left margin into a deep umbilical cleft; margin continuous with the spout. On left side of spout columella of a sunken spire of approximately three turns visible through periostracum.

ANIMAL: Tentaculate area of head rimless, frontal, and oriented ventrally. Dorsal tentacles short and smooth. Lateroventral tentacles deeply grooved laterally, slightly bilobed at tip. Eyes immediately posterior to grooves. Anal opening on dorsal surface of visceral mass beneath mantle. Foot small and triangular with blunt corners.

TYPE SPECIES: *A. cincta* (G. and H. Nevill). Ceylon.

Arthressa evansi, new species

Fig. 1

HOLOTYPE: Bishop Museum, no. 8901. 11 mm. in length; 6 mm. in breadth; collected in a tidepool, Diamond Head Beach Park, Oahu, Hawaii, November, 1956. Paratype: Bishop Museum, no. 8902. 11 mm. in length; 5 mm. in breadth; collected with holotype.

Length of anterior aperture more than half that of shell. Body whorl rounded, not flattened on the left, and with the spiral curve of the shell continued into it. Length of spout less than half shell breadth. Opening of spout triangular with a ventral slit continuous with aperture. Mantle edge smooth in spout. Animal orange, freckled with a darker shade, and with a band of freckling crossing body whorl. Foot similar in coloring to that of body but freckling of a lighter shade. Foot bluntly rounded, not extending anterior to head, and with a groove separating anterior two-thirds from posterior third. Animals extruded a viscid white substance from both posterior spout and anterior aperture. Specimens collected vary from 8–11 mm. in length and from 4–6 mm. in breadth.

The species has been named for the late J. T. Evans.

The specimens were collected in a tidepool on the reef flat of Diamond Head Beach Park, Oahu. They appeared to be associated with the algae *Padina* and *Gracilaria.* The mode of progression on a hard substrate is such that the anterior end of the foot extends forward and attaches to the substrate while the posterior portions move up. The animals readily suspend themselves upside down on the surface of the water, progressing as waves of muscular contraction pass across the foot.

[1] Department of General Science, University of Hawaii. Contribution No. 144 from the Hawaii Marine Laboratory. Manuscript received July 29, 1959.

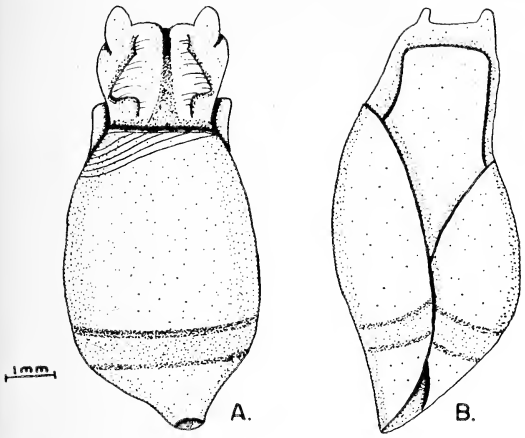

FIG. 1. *Arthressa evansi.* Drawn from the living animal. *A,* Dorsal view; *B,* ventral view.

DISCUSSION

Of the three species now included in *Arthressa, A. evansi* appears to be intermediate in characters between *A. cincta* and *A. elioti. A. evansi* resembles *A. cincta* in coloring and in the smooth mantle edge; it resembles *A. elioti* in the length of the anterior aperture and in the rounded body whorl.

Although Evans (1950) suggested that *Volvatella fragilis* Pease should be retained as it was sufficiently described, no collections of this species have been recorded in Hawaii since the original description. Pease (1860) merely described the type specimen as from the "Sandwich Islands," and the animal was illustrated as being white. Evans (1950) distinguished *Volvatella* from *Arthressa* on the basis of Pease's (1860) description of the anal opening into the posterior spout in *Volvatella;* the anus opens on the dorsal surface of the visceral mass in *Arthressa.* If specimens agreeing with Pease's (1860) description of *Volvatella,* including a posterior anus, are collected in the future, Evans' distinction between the genera will merit recognition; however, it is possible that Pease's description was misleading, and the pore which he described as the anus may have been the pore of the gland which secretes the viscid fluid which these animals emit. If this is the case, Evans could have gone further and entirely suppressed the genus *Volvatella* of Pease.

Evans (1950) described *Arthressa* as a saccoglossan genus, and it should therefore be removed from the position assigned *Volvatella* in the Akeratidae of Thiele (1931). *Arthressa* is of interest in the scheme of opisthobranch relationships in that it is a suctorial form feeding on various algae. The occurrence of a shell and a generalized mantle cavity and alimentary canal suggest that *Arthressa* holds a position in the Saccoglossa analogous to that of *Actaeon* (Fretter and Graham, 1954), which also possesses many prosobranchiate characters.

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The Aleyrodidae (Hemiptera–Homoptera) of New Caledonia

L. J. DUMBLETON[1]

A PREVIOUS PAPER (Proc. R. Ent. Soc. Lond. (B) 25, pts. 7–8, pp. 129–141, 1956) included descriptions of one species of *Dialeurodicus* Ckll. and six species of *Orchamoplatus* Russell. This paper completes the study of a collection of Aleyrodidae from New Caledonia. The material was collected largely by myself during three years' residence in New Caledonia, and as collection was concentrated specifically on this family it is believed that the fauna described here is representative and probably includes a majority of the species.

The following table compares the size and endemicity of the New Caledonian Aleyrodid fauna with those of adjoining areas, in so far as these are known.

The fauna of the New Guinea–Solomons–New Hebrides chain, from which direction an important element of the New Caledonian fauna was probably derived and with which it could be expected to show strong affinities, is unfortunately completely unknown.

The Australian fauna has been little studied and is undoubtedly much larger than the above figures suggest. Those of New Zealand and the South Pacific are reasonably well known. The New Caledonian fauna has affinities with the Australian fauna (for example, in the presence of endemic species of *Aleurocanthus, Bemisia, Dialeurodes,* and *Tetraleurodes*), but there is a relatively stronger element of endemic genera in New Caledonia. There are no obvious affinities between the faunas of New Caledonia and New Zealand. The faunas of New Zealand and the South Pacific are smaller, but while the majority of the New Zealand species are undoubtedly endemic the South Pacific species are predominantly introduced forms occurring on introduced economic crop plants or weeds or on native food plants whose movements about the area have been considerable.

The majority of the species from these four areas belong to the subfamily *Aleyrodinae.* The subfamily Udamoselinae is poorly represented, there being one species of *Aleurodicus* Douglas in Australia and another in Fiji, one species of *Dialeurodicus* in New Caledonia, and one species of the endemic genus *Synaleurodicus* Solomon in Australia. The subfamily Uraleyrodinae is not represented.

AREA	NUMBER OF GENERA			NUMBER OF SPECIES		
	Endemic	Nonendemic	Total	Endemic*	Nonendemic	Total
New Caledonia	3	7	10	25	—	25
Australia	1	12	13	19	3	22
New Zealand	1	3	4	9	1	10
South Pacific	—	7	7	5	4	9

* In each area the number of species presumed to be endemic includes two which are possibly nonendemic.

KEY TO THE GENERA OF THE ALEYRODIDAE OF NEW CALEDONIA
(based on pupal cases)

1. Thoracic tracheal pores, clefts, and combs absent 2
   Thoracic tracheal pores, or clefts, or combs present 6
2. Large elongate brown species, vasiform orifice large, operculum short transverse; lingula long, more than half exposed, occupying whole orifice ..... *Dialeurodicus* Cockerell
   Not as above 3
3. Submarginal line distinct, complete ..... *Tetraleurodes* Q. & B.
   Not as above 4

[1] Entomology Division, D. S. I. R., Christchurch, New Zealand. Manuscript received June 1, 1959.

4. Vasiform orifice triangular; operculum occupies only half orifice; lingula long, pointed, exposed; distinct caudal furrow..... *Bemisia* Q. & B.
   Not as above.....5
5. Marginal teeth well developed, submarginal series of papilla-like pores absent, but simple pale small spots or pores may be present..... *Aleurocanthus* Q. & B.
   Marginal teeth absent or ill-defined, submarginal linear series of papilla-like pores present, broken by 9 processes on each side..... *Leucopogonella* n.g.
6. Abdomen with only 7 visible segments, top-shaped pit-making species..... *Gomenella* n.g.
   Not as above.....7
7. Vasiform orifice long, triangular; operculum occupies half orifice; lingula long, pointed, exposed..... *Parabemisia* Takahashi
   Not as above.....8
8. Thoracic tracheal comb absent..... *Dialeurodes* Cockerell
   Thoracic tracheal comb present.....9
9. Thoracic tracheal comb with 2 teeth, abdominal tracheal comb absent, margin sinuate; submargin with 10 prominent setae on each side; without submarginal papillae..... *Dothioia* n.g.
   Thoracic tracheal comb with 2–many teeth, abdominal comb present, margin not sinuate, submargin without prominent setae, specialized submarginal papillae present..... *Orchamoplatus* Russell

SUBFAMILY UDAMOSELINAE Enderlein

GENUS *Dialeurodicus* Cockerell

Dialeurodicus elongatus Dumbleton. Proc. R. Ent. Soc. Lond. (B), pts. 7–8, pp. 129–131, 1956.

SUBFAMILY ALEYRODINAE Enderlein

GENUS *Aleurocanthus* Quaintance & Baker

KEY TO NEW CALEDONIAN SPECIES
(based on pupal cases)

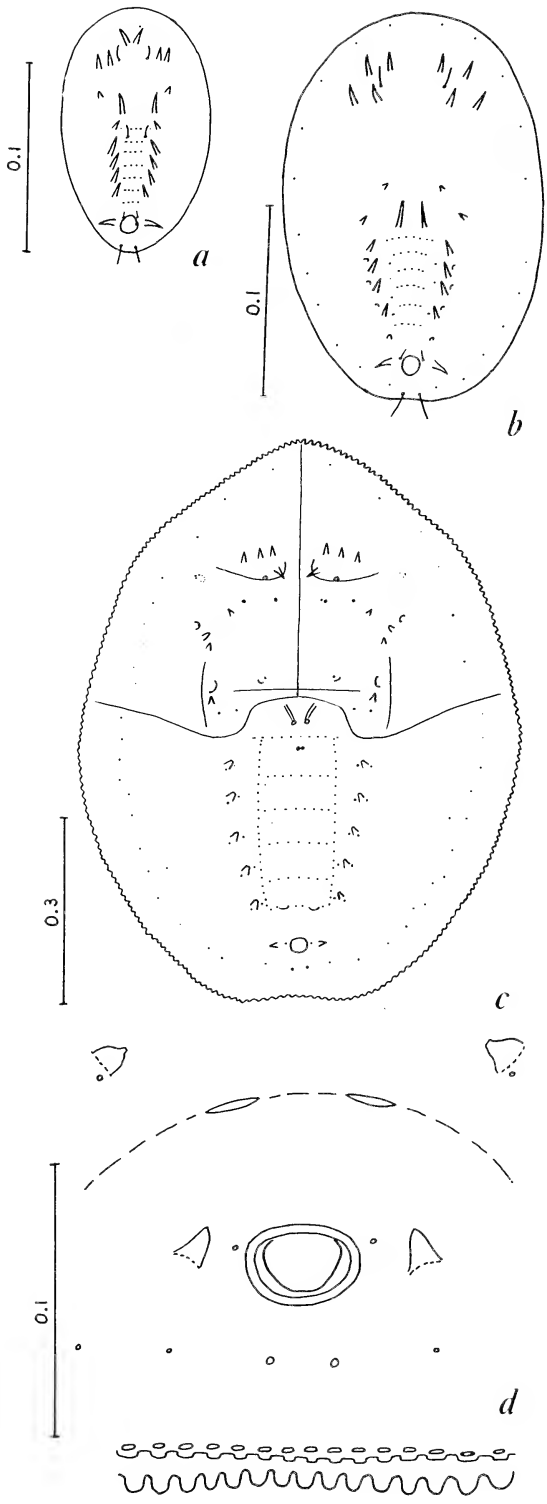
1. Long spines absent.....2
   Long spines present.....3
2. Shape regular ovate or elliptical, without short spinous processes; lateral abdominal rays present..... ***nudus*** sp. n.
   Shape somewhat pointed anteriorly, shallowly emarginate posteriorly, short spinous processes present, lateral abdominal rays absent..... ***brevispinosus*** sp. n.
3. Long spines on thorax only, shape somewhat pointed anteriorly, marginal teeth rounded, lateral abdominal rays present ..... ***spinithorax*** sp. n.
   Many long spines on both thorax and abdomen, shape broadly rounded anteriorly, bluntly pointed posteriorly, marginal teeth pointed, lateral abdominal rays absent..... ***multispinosus*** sp. n.

Aleurocanthus brevispinosus sp. n.
Fig. 1*a–d*

LARVA: Second instar (Fig. 1*a*): Length 0.39 mm., width 0.24 mm. Colour pale. One pair spines anterior to and 2 pairs laterad of cephalic hairlike setae. One pair short and 1 pair long spines posteriorly on thorax. One pair hairlike setae on 1st abdominal segment, those on 8th minute, caudal setae longer, 6 pairs of spines on abdomen. Margin obscurely toothed.

Third instar (Fig. 1*b*): Length 0.60 mm., width 0.41 mm. Sometimes pigmented brown medially. Two pairs of spines anterior to cephalic setae and 2 pairs caudad. One pair short spines on thorax. First abdominal segment with 1 pair paramedian processes, 8th abdominal and caudal setae hairlike, 6 pairs spines on abdomen. Marginal teeth similar to those of pupal case.

PUPAL CASE (Figs. 1*c, d*): Length 0.97 mm., width 0.74 mm. Colour black, eye spots paler. Slightly pointed anteriorly, sides a little concave from one-quarter to one-half length, broadest at mid-length, caudal margin more broadly rounded than anterior but with slight concavity. Not constricted across thoracic tracheal folds. A white wax fringe of columnar elements as wide as teeth and up to half as long as body width. Margin prominently toothed; teeth longer than wide, rounded apically. Submargin not defined by submarginal line, an inner row of teeth present. A continuous row of minute pale spots or



pores, 1 mesad of each outer tooth. A row of minute pores in the position of the submarginal line. Thoracic and abdominal tracheal folds, pores, clefts, and combs absent. Cephalic area posteriorly with 2 paramedian lobes mesad of the eye spots, each bearing 4 short spines. Pores and spines on thorax as in figure. Abdomen, first segment with paramedian processes, a pair of nearly contiguous pores on second segment, a median abdominal ridge laterad of which are 5 pairs of short blunt spinous processes, 1 pair more acute laterad of orifice. Eighth abdominal seta bases laterad of orifice about mid-length. Caudal seta bases slightly closer together than width of orifice and in same line as submarginal line of pores. Vasiform orifice (Fig. 1*d*) subcircular, slightly transverse. Operculum subcordate, filling orifice. Lingula not visible.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, ?Dothio, coll. F. Cohic.

FOOD PLANT: Undetermined.

OTHER MATERIAL: From undetermined hosts, Carenage 17/12/54 and Montagne des Sources 8/4/55, coll. L.J.D., also in association with *A. spinithorax* at Dothio.

This species shows some affinities with *Aleurotrachelus* because the outer boundary of the clear pores mesad of the marginal teeth is raised and simulates an inner row of teeth. In this the species resembles *A. dissimilis* Q. & B. and *A. serratus* Q. & B.

Aleurocanthus multispinosus sp. n.

Fig. 2*a–e*

LARVA. Second instar (Fig. 2*a*): Length 0.34 mm., width 0.2 mm. Colour pale. Cephalic region with 1 pair of paramedian hairlike setae and anterior to these 2 pairs of longer stout spines. Posteriorly on the thorax is 1 pair of short conical spines and a pair of very long

FIG. 1. *Aleurocanthus brevispinosus* sp. n. *a*, Second instar larva; *b*, third instar larva; *c*, pupal case; *d*, pupal case, vasiform orifice and caudal margin. (Scale in mm.)

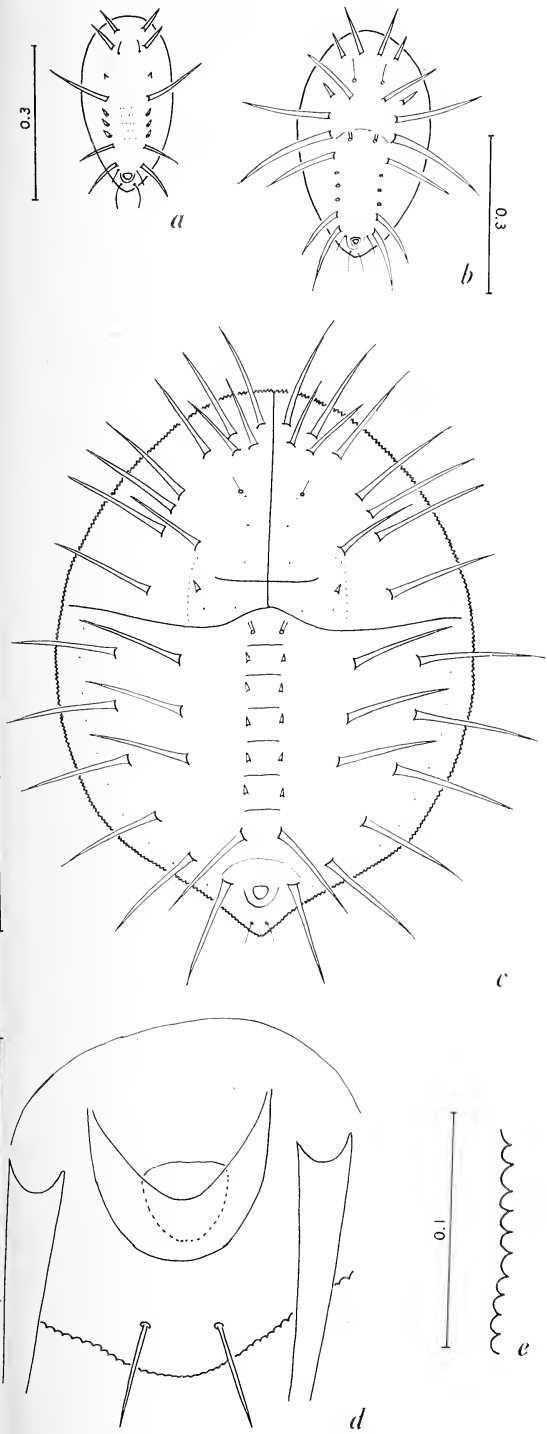


FIG. 2. *Aleurocanthus multispinosus* sp. n. *a,* Second instar larva; *b,* third instar larva; *c,* pupal case; *d,* pupal case, vasiform orifice and caudal margin; *e,* pupal case, margin. (Scale in mm.)

spines. Abdomen with 3 pairs of short conical spines and 2 pairs of long spines. Eighth abdominal setae and caudal setae long, hairlike.

Third instar (Fig. 2*b*): Length 0.54 mm., width 0.31 mm. Colour pale. Cephalic area with 2 pairs of long spines anterior to cephalic setae, lateral pair shorter. Thorax with 2 pairs long spines anteriorly, lateral pair shorter; 2 pairs of long spines posteriorly. Abdomen: 1 pair of paramedian processes on 1st segment, followed by 1 pair of long spines, 3 pairs of pores, 2 pairs of long spines. Eighth abdominal and caudal setae hairlike.

PUPAL CASE (Figs. 2*c–e*): Length 1.0 mm., width 0.71 mm. Colour black. Shape elliptical, wider behind mid-length, posterolateral margins slightly concave and caudal region bluntly conical. No constriction across thoracic tracheal folds and no caudal invagination. Margin (Fig. 2*d*) regularly toothed, teeth not broad and rounded but acute and pointed with the slope of the sides concave. Submargin not defined by submarginal line, finely ridged near margin. Thoracic and abdominal tracheal folds, clefts, pores, and combs absent. Cephalic area with 5 pairs of long, black, somewhat frayed spines anterior to 1 pair of short finer paramedian cephalic setae. Eye spots not evident. Thoracic area with 5 pairs of long spines and 1 short thornlike spine midway between median line and margin metathorax. Abdomen with ill-defined median ridge, segmentation ill-defined, rhachis absent. Segment 1 with a pair of paramedian processes. Segments 2–6 each with 1 pair of short thornlike paramedian spines. Segment 7 with long spines. Eighth segment with 1 pair of long stout spines, setae absent. Caudal setae short, hairlike, with bases about same width as vasiform orifice but nearer the margin than to the orifice. Five pairs of long lateral spines in same line as 8th abdominal spines and 3 pairs of long discal setae midway between paramedian and lateral spines. Vasiform orifice (Fig. 2*e*) raised, not clearly discernible, hemispherical. Operculum filling orifice. Lingula not discernible.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

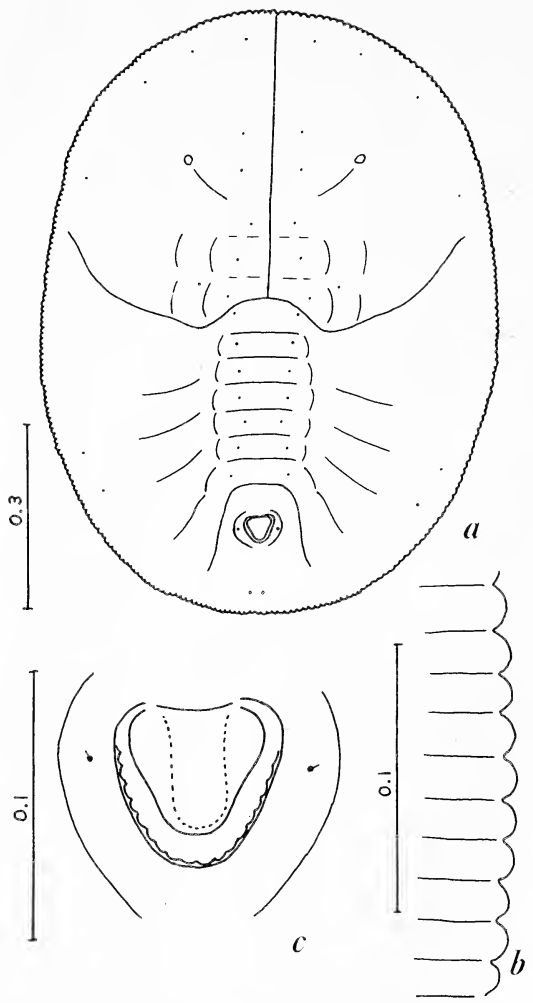


FIG. 3. *Aleurocanthus nudus* sp. n. *a*, Pupal case; *b*, pupal case, margin; *c*, pupal case, vasiform orifice. (Scale in mm.)

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Montagne des Sources, 3,000 ft., coll. L.J.D.

FOOD PLANT: *Hibbertia* sp.

Similar to *A. calophylli* Kotinsky from Fiji but differing in the form of the marginal teeth.

Aleurocanthus nudus sp. n.
Fig. 3*a–c*

PUPAL CASE (Fig. 3*a–c*): Length 1.0 mm., width 0.72 mm. (holotype) but reaching 1.4 mm. long. Colour black. Shape broadly elliptical, rounded anteriorly and posteriorly. Rather flat but with median ridge and 2 thoracic lateral ridges. Wax fringe white about one-third body width. There is a submarginal line of wax, an inverted U-shaped wax line more or less contouring the adult head and thorax, and 5 or 6 transverse lines on the abdomen. Inside the marginal line of wax there are narrow radial striae of wax and the disc is powdered with wax. Margin (Fig. 3*b*) strongly toothed, teeth rounded, 7 teeth in 0.1 mm. Submargin not defined from dorsal disc, radially striate, striae same width as teeth; with a number of minute simple pores, 3 cephalic, 2 thoracic, 2 mid-length on abdomen. Thoracic and abdominal tracheal folds, pores, combs, and clefts absent. Eye spots present, subtriangular. Cephalic and thoracic areas without setae, pores as in figure. Abdomen, segment 1 with 1 pair paramedian pores, segments 2–6 limited laterally and with paramedian pores. Between segments 3 and 6, 4 lateral rays on each side. Seta bases on 8th abdominal segment on orifice rim about mid-length of orifice. Caudal seta bases close together, nearer margin than orifice.

Vasiform orifice (Fig. 3*c*) subcordate, 0.06 mm. wide, 0.065 mm. long, internally toothed. Operculum subcordate, filling orifice 0.05 mm. long. Lingula parallel-sided, apex rounded.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Tinip, coll. L.J.D., 4/11/54.

FOOD PLANT: *Leucopogon* sp. On upper surface of leaf.

This species comes nearest the genus *Aleurocanthus* and is similar to *dissimilis* Q. & B. in the absence of long spines and to *T-signatus* Mask., *serratus* Q. & B., and *spinosus* Kuwana in the presence of lateral rays on the abdomen.

Aleurocanthus spinithorax sp. n.
Fig. 4*a–d*

LARVA. Second instar (Fig. 4*a*): Length 0.4 mm., width 0.27 mm. Colour pale laterally, brown medially. Margin with short broad truncate teeth. Cephalic area with 2 pairs of short conical spines anterior to cephalic hairlike setae

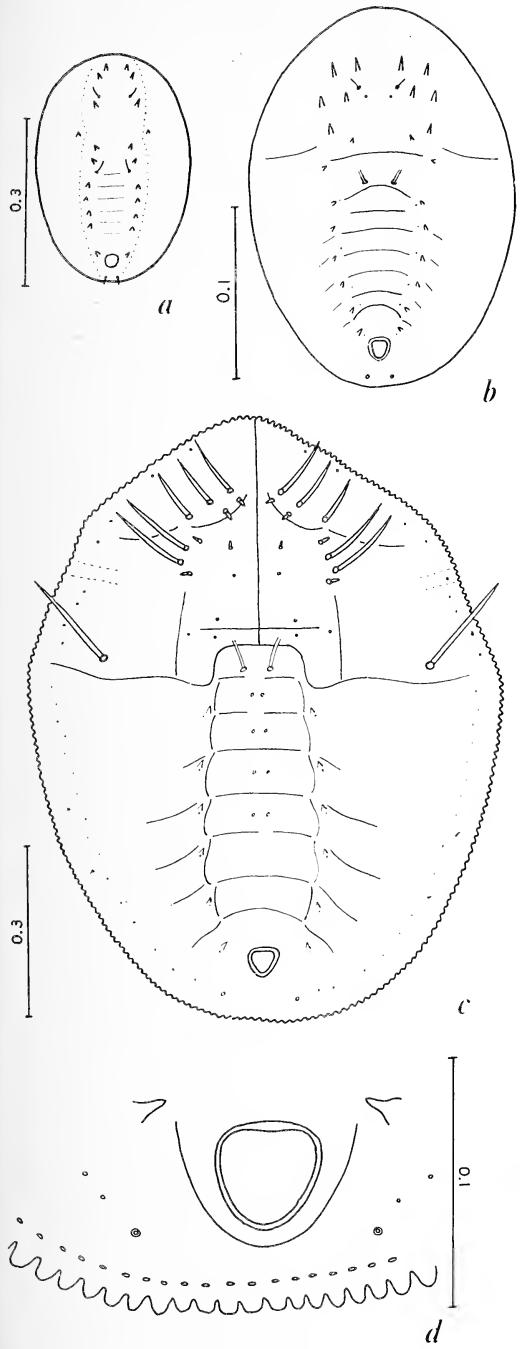


FIG. 4. *Aleurocanthus spinithorax* sp. n. *a*, Second instar larva; *b*, third instar lava; *c*, pupal case; *d*, pupal case, vasiform orifice and caudal margin. (Scale in mm.)

and 1 pair posterior. Thoracic area with 3 pairs of short conical spines. Abdomen: First segment with 1 pair hairlike setae, following segments with 4 pairs of short conical spines, 8th abdominal setae small or absent, 1 pair of short conical setae laterad of orifice, caudal setae hairlike.

Third instar (Fig. 4*b*): Length 0.68 mm., width 0.52 mm. Colour brown. Marginal teeth as in pupal case with pore mesad of each. Cephalic area with 2 pairs of short conical spines anterior to and 2 pairs posterior to cephalic hairlike setae. Thoracic area with 3 pairs of short conical setae. Abdomen: First segment with 1 pair of paramedian processes followed by 6 pairs of short conical spines. Eighth abdominal setae not discernible, caudal setae hairlike.

PUPAL CASE (Fig. 4*c, d*): Length 1.1 mm., width 0.82 mm. Colour dark brown to black. Shape elliptical but slightly pointed anteriorly, angulated opposite end of transverse moulting suture and again at 2 points midway to anterior median line. Very slightly emarginate caudally. Not constricted across thoracic folds. Margin toothed, 9 teeth in 0.1 mm., teeth longer than wide, apex rounded. Thoracic tracheal folds indicated; pores, clefts, and combs absent. Abdominal tracheal folds, pores, clefts, and combs absent. Submargin with a continuous row of minute simple circular pores one behind each marginal tooth, not defined mesally by submarginal line, without setae but with 4 minute pores on each side of thorax and 2 on each side of abdomen mesad of the line of pores behind the teeth. Cephalic area delimited by line subparallel to margin commencing anterior to thoracic fold and meeting at median suture. On each side a group of 3 long spines and 2 short spines. Thoracic area with the median part limited by lateral lines midway between median line and margin. Near the anterior end of these lines, on each side, a group of 2 long and 2 short spines. In the posterior lateral angle of the metathorax, and nearer the margin than the median line, is a single long spine. Abdomen broadly ridged in the median area with the segments limited laterally and with 3 rays extending halfway to margin from intersegmental sutures 4–5,

5–6, and 6–7. Segment 1 subrectangular with 2 paramedian processes close together. Segments 2–5 each with 2 paramedian nearly contiguous pores. Laterad of the boundary of the median ridge are 4 short spines opposite sutures 2–3, 3–4, 4–5, and 5–6, a similar one at mid-length on 7, and 1 laterad of orifice on 8. The 8th abdominal seta is not discernible. Caudal seta bases as wide apart as spines on 8th segment. Vasiform orifice subcordate (Fig. 4*d*). Operculum fills orifice. Lingula not discernible.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Dothio, coll. F. Cohic.

FOOD PLANT: An undetermined climbing plant.

This species is very similar in facies to *A. brevispinosus* and shows affinities with *Aleurotrachelus* Q. & B. The moulted skins of 2 larval instars are usually adhering to the dorsum of the pupal case.

GENUS *Bemisia* Quaintance & Baker

Bemisia cordylinidis sp. n.
Fig. 5*a–c*.

LARVA. Third instar (Fig. 5*a*): Length 0.7 mm., width 0.42 mm. Resembles pupal case but anal furrow less developed and caudal setae long and stout.

PUPAL CASE (Fig. 5*b, c*): Length 1.15 mm., width 0.80 mm. Colour transparent or white. Shape elliptical, flat. No constriction across thoracic pores, little or no caudal invagination. Margin finely crenulate. Submargin not separated from dorsal disc. Anterior and posterior marginal setae present. Area between submargin and tubercles with dense hemispherical pustules in radial arrangement, each row tending to consist of tubercules 2 deep. Cephalic area with 2 pairs of minute paramedian setae. Thoracic area with tracheal folds, pores, combs, and clefts absent; 3 pairs of tuberculate warts nearly midway between median line and margin. Abdomen, first segment with 1 pair of minute, widely spaced setae. Segments 1–5 with a median tuberculate wart, less developed on segments 1, 4, and 5. A

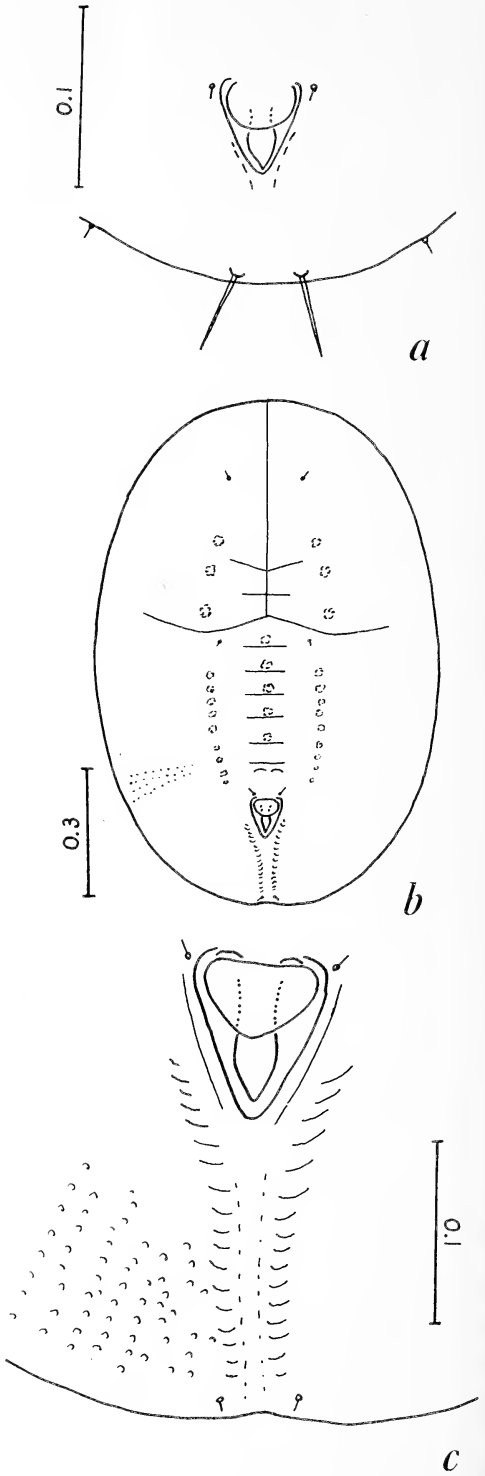


FIG. 5. *Bemisia cordylinidis* sp. n. *a,* Third instar larva, vasiform orifice and caudal margin; *b,* pupal case; *c,* pupal case, vasiform orifice and caudal margin. (Scale in mm.)

row of 7 or 8 tubercles on each side, the posterior members tending to become continuous with the ridges bounding the anal furrow. These abdominal tubercles and those on the thorax outline the adult body. Seventh segment narrower than 6 and 8. Eighth segment with a pair of minute setae level with anterior margin of vasiform orifice, bases as wide apart as orifice width. Vasiform orifice (Fig. 5*c*) subtriangular, long, acutely pointed, with 2 or 3 oblique ridges on each side of apical half. Operculum semicircular, not more than half the length of orifice. Lingula long, exposed, spatulate, pointed. Ridges of anal furrow contouring the orifice where the tubercles are somewhat pectinated, smooth tubercles between orifice and cauda. Caudal setae minute, on ends of furrow ridges near margin.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Montagne des Sources, coll. L.J.D.

FOOD PLANT: *Cordyline* sp.

The tuberculation suggests *Asterobemisia* Trehan but the thoracic and abdominal tracheal folds and combs are absent. The species resembles *Bemisia shinanoensis* Kuwana but lacks setae on the abdomen.

GENUS *Dialeurodes* Cockerell

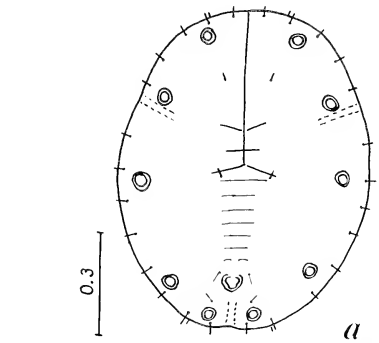
KEY TO NEW CALEDONIAN SPECIES (based on pupal cases)

1. With 5 large simple pores on each side..... .....***dothioensis*** sp. n.
   No large pores.....2
2. Pale species, adult body outlined by tuberculate line; transverse moulting suture not continued anteriorly; anterior and posterior marginal, 8th abdominal and caudal setae present.....***psychotriae*** sp. n.
3. Black species; transverse suture continued anteriorly and meeting in median line and enclosing eye spots, lateral abdominal line passing from transverse suture to level with orifice; without setae..... .....***dumbeaensis*** sp. n.

Dialeurodes dothioensis sp. n.

Fig. 6*a, b*

PUPAL CASE (Fig. 6*a, b*): Length 1.0 mm., width 0.73 mm. Colour transparent or white. Shape elliptical, widest at mid-length, with slight concavities in the thoracic and abdominal tracheal pore areas. Wax secretion in the form of pale blue filaments. Margin somewhat irregularly toothed, anterior and posterior marginal setae present. Submargin not defined from dorsal disc, with 12 short spearhead-like marginal setae on each side, 5 anterior to thoracic fold and 7 posterior to it. Cephalic area with 1 pair of paramedian cephalic setae and anterior to these and nearer to the margin 1 pair of very large simple



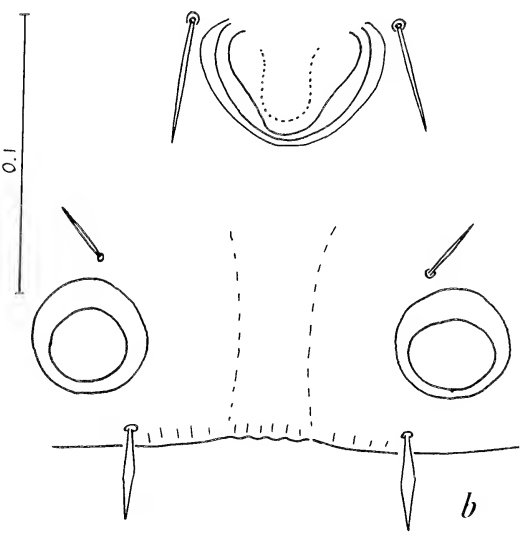


FIG. 6. *Dialeurodes dothioensis* sp. n. *a*, Pupal case; *b*, pupal case, vasiform orifice and caudal margin. (Scale in mm.)

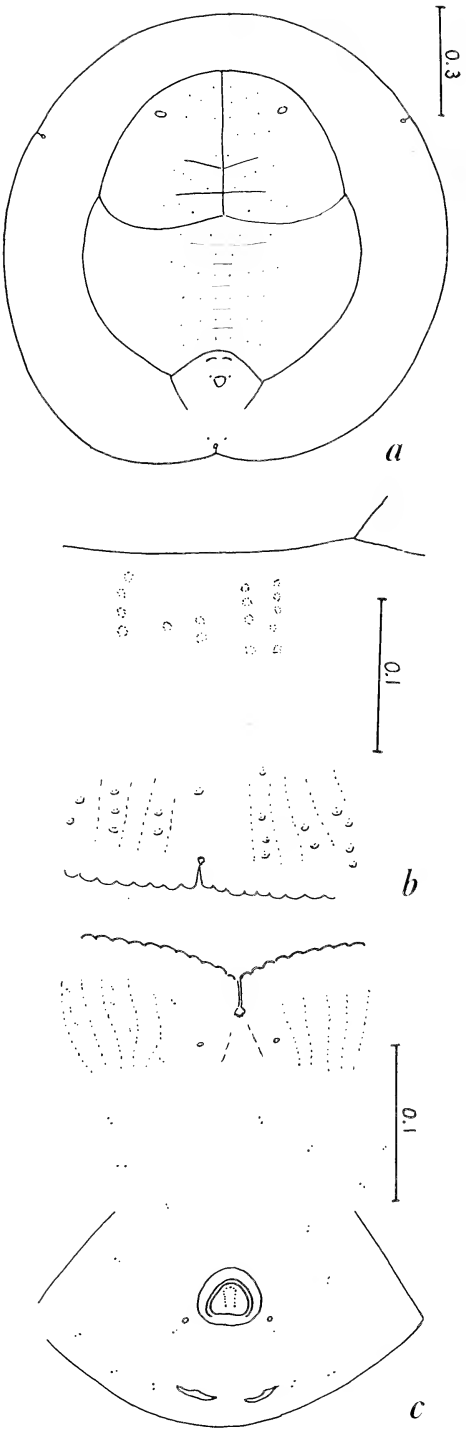


FIG. 7. *Dialeurodes dumbeaensis* sp. n. *a,* Pupal case; *b,* pupal case, thoracic tracheal pore; *c,* pupal case, vasiform orifice and caudal margin. (Scale in mm.)

pores with thick walls of external diameter 0.045 mm. Thoracic area with 1 pair of similar pores immediately anterior to thoracic folds which are not sculptured and end in a comb of about 5 minute teeth. Abdomen with three pairs of large simple pores near margin, one opposite the transverse moulting suture, one slightly anterior to the orifice, and one caudad of the orifice. Abdominal tracheal fold and comb not evident. First abdominal segment with one pair of short setae. Eighth abdominal setae present longer than orifice, bases level with anterior margin of orifice. One short seta cephalad of each large caudal pore. Caudal setae caudad of these pores. Vasiform orifice (Fig. 6*b*) subcordate, 0.06 mm. wide, 0.045 mm. long, no teeth on margin. Operculum nearly filling orifice, 0.04 mm. wide, 0.035 mm. long. Lingula included, constricted near base, 0.02 mm. long, 0.015 mm. wide, subtruncate apically.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Dothio River Bridge, coll. F. Cohic, 17/6/53.

FOOD PLANT: Undetermined.

This species is closely related to *D. decempunctata* Q. & B. but differs in that the thoracic fold is not between the first and second pores, in the spearhead shape of the marginal setae and in having only one seta anterior to each caudal pore. It differs from *D. viburni* Takahashi in having only one seta anterior to each caudal pore and in the form of the marginal setae. It belongs to the subgenus *Dialeuropora* Q. & B.

Dialeurodes dumbeaensis sp. n.

Fig. 7*a–c*

PUPAL CASE (Fig. 7*a–c*): Length 1.25 mm., width 1.2 mm. Colour black. Shape subcircular, faintly constricted across thoracic folds but invaginated caudally at abdominal tracheal pore. The marginal fringe, of white wax rods half as wide as body, may split in stellate fashion into 10 rays. Margin with rounded teeth, 10 teeth in 0.1 mm., anterior and posterior marginal setae present. The submarginal line is higher in elevation than the margin and the dorsal

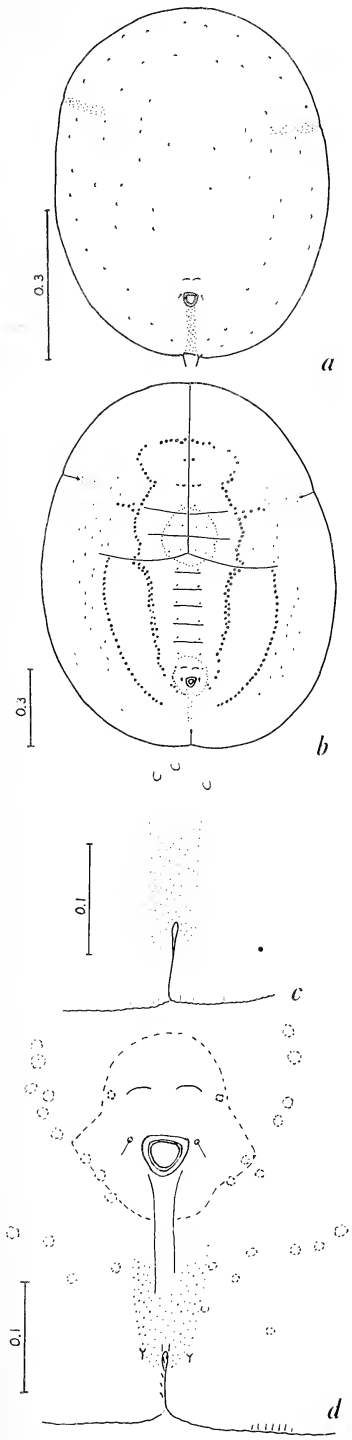


FIG. 8. *Dialeurodes psychotriae* sp. n. *a,* Third instar larva; *b,* pupal case; *c,* pupal case, thoracic tracheal pore; *d,* pupal case, vasiform orifice and caudal margin. (Scale in mm.)

disc and the transverse and median moulting sutures are also elevated. Submargin radially striate 0.25 mm. wide, on outer half with radial rows of 4–5 minute circular poriferous papillae mesad of alternate teeth, intervening areas darker, inner half with radial rows of less well-defined subcircular nonporiferous papillae. Submarginal line on cephalothorax continuous with transverse moulting suture. Cephalic area with eye spots oval, long axis 0.03 mm. long, oblique, enclosed by submarginal line, without setae or evident pores. Thoracic area, without setae or evident pores. Tracheal folds not visible dorsally, cleft present but closed, pore (Fig. 7*b*) minute, subcircular, minutely toothed, inset from margin. Cephalothorax with scattered irregular minute pores. Abdomen. Submarginal line of abdomen ending level with orifice, the two halves joined by a semicircular raised line anterior to orifice, from the junction on each side a short raised line runs mesocaudally so that the orifice is enclosed except caudally. Abdomen, segments 1–6 subequal in length, without setae but with transverse row of minute pores, seventh segment half as long. Vasiform orifice (Fig. 7*c*) semicircular, 0.03 mm. long, 0.035 mm. wide. Operculum semicircular, 0.02 mm. long, 0.03 mm. wide, filling orifice. Lingula not visible. Eighth abdominal setae represented by pores, level with anterior margin of orifice and distant from it.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Dumbea, coll. L.J.D., 9/6/52.

FOOD PLANT: *Homalium* sp.?

This species would run to *Dialeurodes* subgenus *Gigaleyrodes* Q. & B. in Quaintance & Baker's key, and is reminiscent of *D.(G.) cerifera* Q. & B.

Dialeurodes psychotriae sp. n.

Fig. 8*a–d*

LARVA. Second instar: Length 0.30 mm., width 0.28 mm. Elliptical. Colourless. Similar to 3rd instar but tubercles absent and marginal teeth more distinct.

Third instar (Fig. 8*a*): Length 0.75 mm., width 0.56 mm. Elliptical. Colourless. Without tuberculate pattern but with scattered irregular small tubercles. Caudal setae situated on margin, strong. Tracheal pores with few teeth on margin, no clefts. Tracheal folds present, dotted. Margin as in pupal case.

PUPAL CASE (Fig. 8*b–d*): Length 1.44 mm., width 1.15 mm. Colourless except for a circular pigmented middorsal area on meso- and metathorax and anterior half of first abdominal segment, and another more elongate area on 7th and 8th abdominal segments including the orifice and extending caudad of it. Shape elliptical, flat, widest at mid-length. Margin slightly crenulated nearly entire with numerous marginal ridges and grooves extending a short distance mesally, anterior and posterior marginal setae present. Submargin not defined from dorsum. Body of adult outlined by a row of tubercles, single on cephalothorax but tending to be double on abdomen and ending caudad of orifice. Between this and the margin on the abdomen is a second row of slightly smaller tubercles in single series. Thoracic tracheal folds present, marked by dots, extending from pore to line of tubercles where they are dilated. Pore (Fig. 8*c*) simple, without teeth, distant 0.05 mm. from margin, cleft present. Abdomen with scattered small circular pores especially between margin and outer row of tubercles. Setae not evident on segment 1. Posterior half of 6th abdominal segment between paramedian pores is finely spinulose. Eighth abdominal setae 0.03 mm. long level with anterior margin of orifice, distant from orifice. Caudal setae 0.01 mm. long, one on each side of tracheal pore at mid-length. Vasiform orifice (Fig. 8*d*) subcordate, not toothed internally on lateral or posterior margins, 0.04 mm. long, 0.04 mm. wide. Operculum filling orifice, 0.03 mm. long, 0.03 mm. wide. Lingula not exposed, parallel sided, apex rounded, as long as operculum. Abdominal tracheal fold present, marked by dots. Pore simple, distant from margin by closed cleft.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Plum, coll. L.J.D.

FOOD PLANT: *Psychotria deplanchei.*

This species would run to the subgenus *Gigaleyrodes* in Quaintance & Baker's key although the tracheal pore differs. A similar tuberculation of the dorsal disc occurs in *Dialeurodes (Dialeuronomada) dissimilis* Q. & B. in which however the orifice is toothed.

GENUS *Dothioia* nov.

PUPAL CASE: Apparent margin not toothed, margin reflexed with small conical teeth. Thoracic and abdominal tracheal folds not evident. Thoracic tracheal pore represented by two projecting processes. Margin in the position of the abdominal tracheal pore with four or five ill-defined teeth. Apparent body margin sinuate, i.e., concave between the submarginal setae of which there are five on each side of the cephalothorax and four on the abdomen in addition to the caudal setae.

TYPE SPECIES: *D. bidentatus* sp. n.

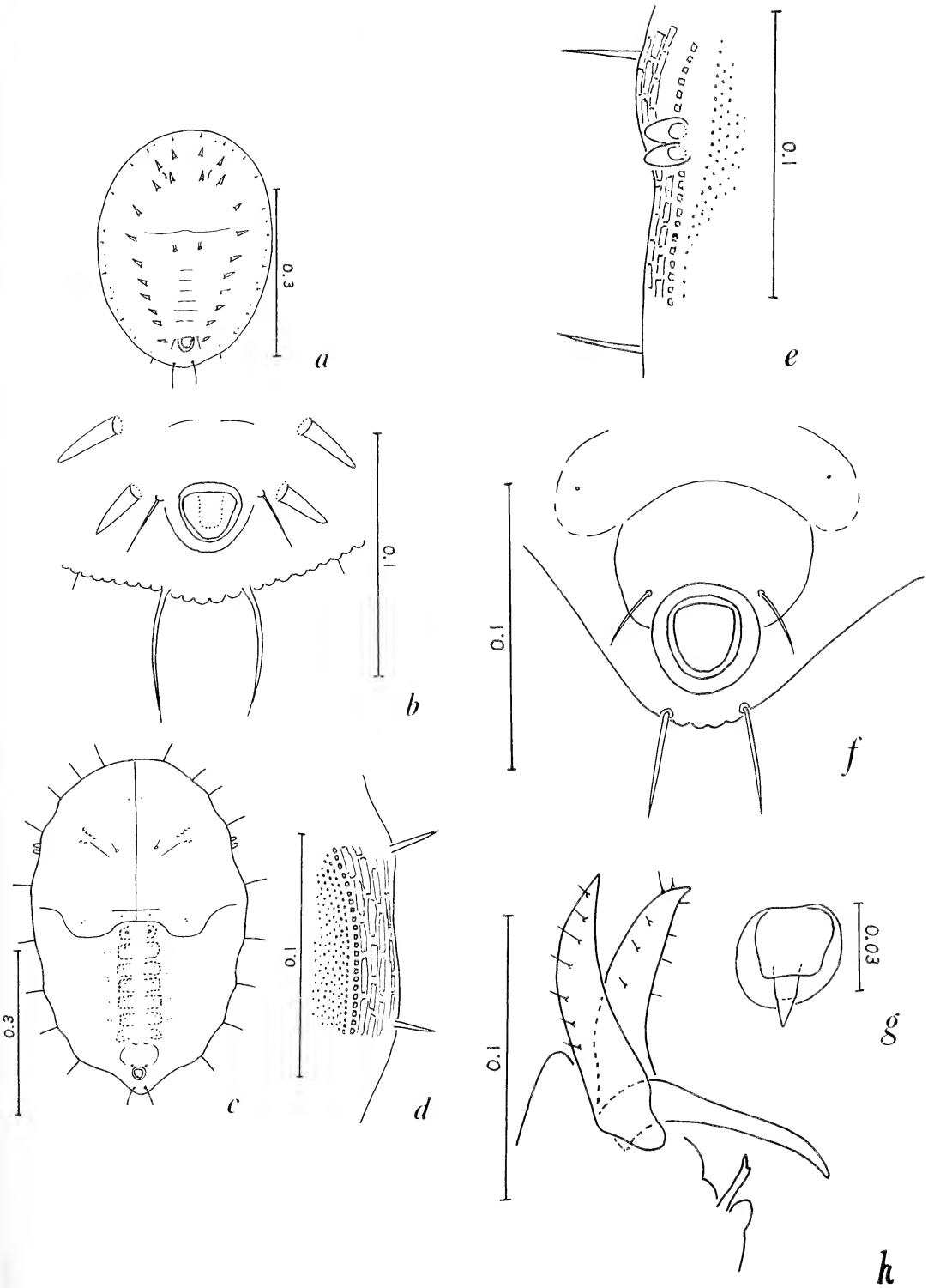
Dothioia bidentatus sp. n.

Fig. 9*a–h*

LARVA. Third instar (Figs. 9*a*, *b*): Length 0.45 mm., width 0.31 mm. Shape elliptical. Colour pale. Margin toothed. Submargin with 10 fine short setae on each side. Cephalic area with one pair of fine setae and four pairs of spines. One pair of posterolateral thoracic spines. Abdomen, one pair of paramedian processes on first segment, seven pairs of spines laterad, eighth abdominal setae hairlike, level with orifice, caudal setae long.

PUPAL CASE (Fig. 9*c–f*): Length 0.75 mm., width 0.56 mm. Colour black. Wax pattern of narrow linear raised elements; a median line along suture on anterior half of cephalothorax, a short transverse line on first abdominal segment, and a longer oblique line in posterolateral angle of thorax. Apparent margin not toothed,

FIG. 9. *Dothioia bidentatus* sp. n. *a,* Third instar larva; *b,* third instar larva, vasiform orifice and caudal margin; *c,* pupal case; *d,* pupal case, margin; *e,* pupal case, thoracic tracheal pore; *f,* pupal case, vasiform orifice and caudal margin; *g,* female, vasiform orifice and lingula; *h,* male, claspers and aedeagus. (Scale in mm.)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sinuate, with 7 rounded prominences on each side. True margin may be visible between prominences near cauda and there show small conical teeth. Margin (Fig. 9*d*) reflexed ventrally, marked by a line of small conical teeth mesad of which is a clear membranous line separating the venter which is densely covered by small circular pigmented tubercles. Apparent margin with 9 submarginal setae 0.05 mm. long, 4 anterior to thoracic pore, 1 on thorax caudad of pore, and 4 on the abdomen in addition to the caudal seta on each side. Submargin in bleached specimens with elongated pigmented rectangular thickenings internally. Cephalic area with a pair of cephalic setae and anterolaterad of these about 4 small tubercles in the position of the eye spots. Thoracic tracheal folds not evident, pores (Fig. 9*e*) represented by 2 projecting rounded processes 0.01 mm. long. Abdomen with median abdominal ridge. Segments clearly defined laterally by raised tuberculate line, the lateral margins of the seventh segment produced caudad. Eighth abdominal setae as long as orifice, distant from it, and level with its anterior margin. Vasiform orifice (Fig. 9*f*) subcircular, 0.04 mm. long, internally ribbed. Operculum filling orifice. Lingula not visible. Abdominal tracheal fold not evident, no pore or comb, caudal margin with 4 or 5 indistinct teeth between caudal setae.

ADULT: (Fig. 9*g–h*): Pale yellow. Wings immaculate. Forewings with R_S and Cu present. Hind wings with single vein. Antennae with third segment longer than 4–7 combined, 4 and 7 subequal and shorter than 5 and 6, which are subequal. About 18–19 setae in comb on hind tibia. Lingula (Fig. 9*g*) with sides subparallel, apex conical and reduced in thickness. Male with claspers slender, pointed; aedeagus (Fig. 9*h*) tapering slightly falcate apically.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Dothio River, coll. L.J.D., 9/5/53.

FOOD PLANT: Undetermined.

GENUS *Gomenella* nov.

PUPAL CASE: Circular. Submargin defined by submarginal line. Submarginal setae present or absent. Dorsum densely covered with simple pores which may be large and contiguous. Thoracic tracheal pores flasklike, folds absent. Abdominal tracheal fold and pore present or absent. Anal furrow present. Vasiform orifice subcircular, operculum filling it. Lingula fingerlike. Only 7 visible abdominal segments. Top-shaped, pit-making species.

TYPE SPECIES: *G. multipora* sp. n.

One of the species described below resembles *Aleurochiton* Tullgren in the presence of dense dorsal pores but differs as above and also in the absence of a vertical wax palisade. The other species conforms to *Dialeurodes* (s.g. *Gigaleyrodes*) except for the reflexed margins which suggest *Tetralicia* Harrison but it is otherwise unlike that genus. In assigning these 2 species to a new genus, stress is placed on the apparent presence of only 7 visible abdominal segments and the top-shaped form correlated with the pit-making habit in spite of the differences noted in the following key.

KEY TO THE NEW CALEDONIAN SPECIES
(based on pupal cases)

Submargin reflexed, without setae; dorsum without dense large contiguous pores; abdominal tracheal pore present....***reflexa*** sp. n.

Not as above.....***multipora*** sp. n.

Gomenella multipora sp. n.
Fig. 10*a–f*

LARVA. First instar (Fig. 10*a*): Length 0.13 mm., width 0.10 mm. Submarginal setae as in other stages but with very long caudal setae functional legs and long antennae, without large pores on dorsum, vasiform orifice more elongate.

Second instar (Fig. 10*b*): Distinguished from other stages by sparse regularly arranged dorsal pores on thorax and a line of four subdorsal pores on each side of abdomen.

Third instar (Fig. 10*c*): More numerous pores on the thorax, 3 rows of 3 pores on each side of abdomen not extending across median line as in pupal case. Two pores on each side of orifice.

PUPAL CASE (Fig. 10*d–f*): Length 0.5 mm., width 0.5 mm. Pupae yellow. Pupal case colour-

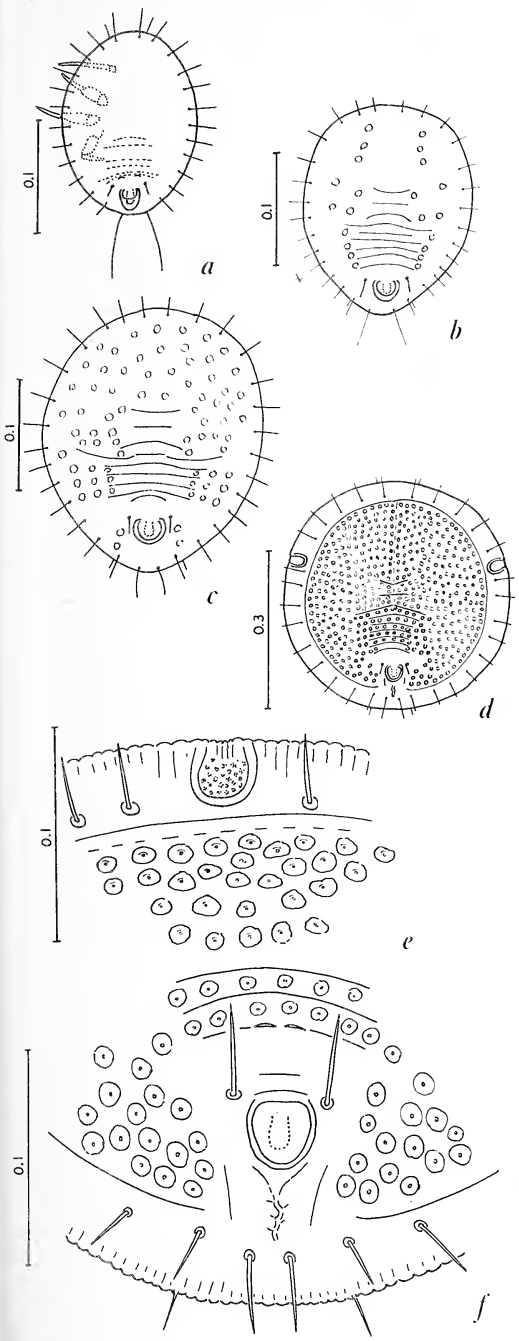


FIG. 10. *Gomenella multipora* sp. n. *a,* First instar larva; *b,* second instar larva; *c,* third instar larva; *d,* pupal case; *e,* pupal case, thoracic tracheal pore; *f,* pupal case, vasiform orifice and caudal margin. (Scale in mm.)

less. Shape circular, flat dorsally but convex ventrally, i.e., top-shaped where it fits into a pit on the leaf. Bearing a thick dorsal plate of wax which covers the body except for the submargin, orifice, and caudal area. Margin crenulate, anterior and posterior marginal setae present. Submarginal groove present, contouring the margin except caudally. Fourteen submarginal setae on each side, 5 anterior to thoracic tracheal pore and 9 posterior. Thoracic tracheal fold absent. Thoracic pore (Fig. 10*e*) flask-shaped, reaching mesally nearly to submarginal groove; walls thicksided with numerous thickenings, 4 or 5 small teeth on lip of pore which is slightly concave. Cephalic, thoracic, and abdominal areas of dorsal disc covered with dense circular simple pores. Lateral arms of transverse moulting suture straight meeting in very obtuse angle medially. Abdominal area densely covered with circular simple pores 0.01 mm. diameter. Segments each with a single transverse row of pores. Only 7 segments apparent. Eighth abdominal setae longer than orifice, bases distant from rim, and level with anterior margin of orifice. Vasiform orifice (Fig. 10*f*) subcircular, 0.04 mm. long, 0.037 mm. wide. Operculum filling orifice. Lingula subparallel-sided, apex rounded. Anal furrow present between posterior end of vasiform orifice and caudal setae, the ridges conturing the posterior part of the orifice. Caudal setae subequal in length to submarginal setae, bases nearer to margin than to orifice and narrower than orifice. Abdominal tracheal fold and pore absent.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Tinip, coll. L.J.D., 4/11/54.

FOOD PLANT: Undetermined.

Occurring in pits on the tomentose undersurface of the leaf.

Gomenella reflexa sp. n.

Fig. 11*a–g*

LARVA. ? Instar (Fig. 11*a–c*): Length 0.26 mm., width 0.21 mm. Colour pale except diamond-shaped area surrounding orifice and 8th

segment. Subcircular dorsal surface, body top-shaped. Margin barely crenulated, submarginal pores broad. Thoracic tracheal fold visible on ventral surface as asperities. Thoracic tracheal combs (Fig. 11*b*) present as small marginal teeth with 2 or 3 obscure teeth mesally. Thoracic and abdominal segmentation indistinct. Legs tapering, then widened distally. Vasiform orifice (Fig. 11*c*) subcordate with a small cell apically. Eighth abdominal setae short, fine, level with anterior margin of orifice. Operculum subcordate, filling orifice. Lingula included, parallel-sided, apex rounded. Caudal setae short, fine, bases not as far apart as bases of 8th abdominal setae.

These larvae occurred in pits on the upper surface of the leaves of *Grevillea gillivrayi* on Mont Dore (coll. L.J.D.). The disc of the dorsum is covered with a shieldlike raised white wax plate, except for the orifice and the caudal area (Fig. 11*d*). They are considered to be those of *reflexa* because of the brown pigmentation and the pit-making habit on the upper surface of the leaf.

PUPAL CASE (Fig. 11*e–g*): Length 0.60 mm., width 0.58 mm. Colour dark brown. Shape circular, flat dorsally but convex ventrally where it fits into a pit on the leaf. Apparent margin straight. Margin reflexed ventrally, distant about 0.1 mm. from apparent margin except posteriorly where it arises from near the anterior end of the abdominal tracheal pore, crenulated or with 11–12 short rounded teeth in 0.1 mm. A submarginal line between the apparent margin and the margin, nearer to the latter. Area between margin and apparent margin radially striate. Setae absent, sutures and segmentation as in Figure 11*e*. Minute scattered simple pores on body. Thoracic tracheal folds (Fig. 11*f*) present, beset with minute dots. Thoracic pore flask-shaped, invaginated, and with thick sides, the inner walls covered with short transverse projections, outer margin toothed. Abdomen, first abdominal segment short, 7th apparently

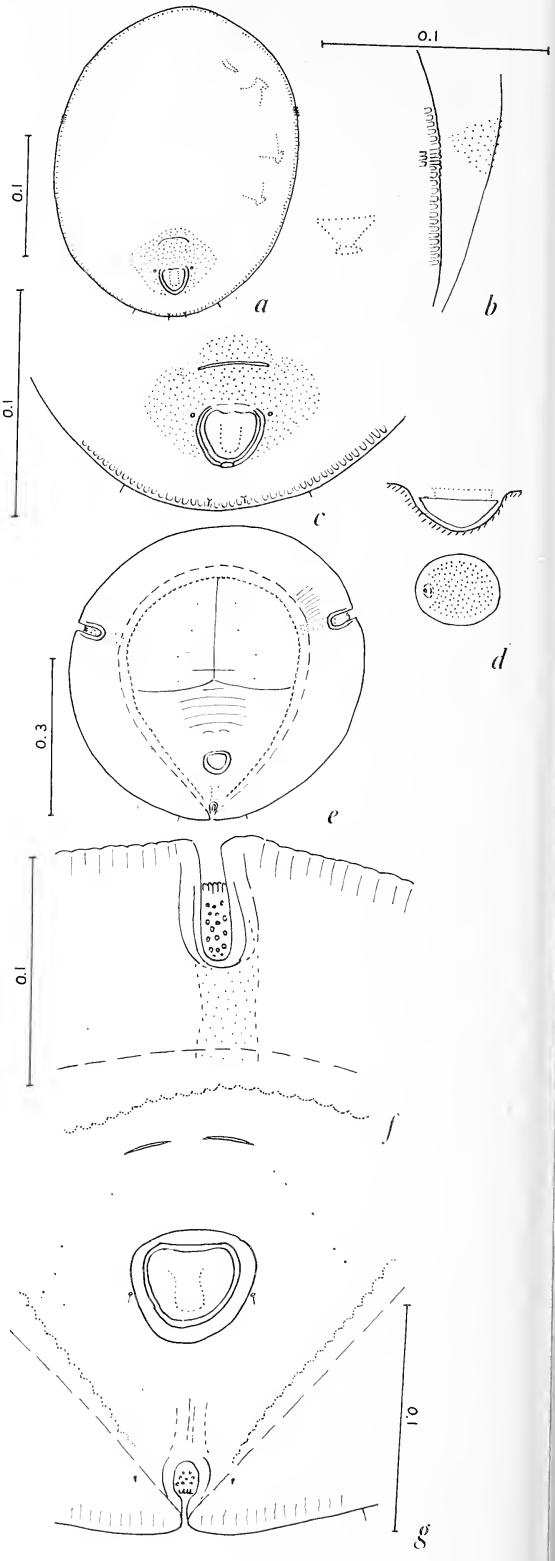


FIG. 11. *Gomenella reflexa* sp. n. *a*, Third instar larva; *b*, third instar larva, thoracic tracheal pore; *c*, third instar larva, vasiform orifice and caudal margin; *d*, third instar larva, wax plate and pit; *e*, pupal case; *f*, pupal case, thoracic tracheal pore; *g*, pupal case, vasiform orifice and caudal margin. (Scale in mm.)

absent. Abdominal tracheal fold present, without dots, abdominal tracheal pore similar to thoracic pore. Vasiform orifice (Fig. 11*g*) cordate, 0.05 mm. long, 0.05 mm. wide. Eighth abdominal setae minute, at half the length of orifice. Operculum 0.04 mm. long, 0.04 mm. wide, subcordate, completely filling orifice. Lingula 0.025 mm. long, 0.012 wide, finger-like, slightly constricted before base, apex rounded, completely included.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Riviere des Pirogues, coll. L.J.D., 31/7/54.

FOOD PLANT: *Maxwellia* sp.

The species is unusual in that it occupies pits on the dorsal surface of the leaves; the ventral surface of the leaves bears dense brown tomentum.

GENUS *Leucopogonella* nov.

PUPAL CASE: Margin entire or teeth only faintly indicated. A submarginal linear row of pores or papillae, giving the effect of an inner row of teeth. Submargin not separated from dorsal disc except in pale species. The row of pores is broken by 9 processes on each side, producing either 2 minute teeth on the margin or a marginal concavity between these points. Thoracic tracheal folds, pores, and combs absent. Without rhachis. Without contiguous pores on first abdominal segment. Vasiform orifice small subcordate. Eighth abdominal setae slightly anterior to orifice. Caudal setae close together, bases not as wide apart as width of orifice.

TYPE SPECIES: *L. sinuata* sp. n.

This genus perhaps comes nearest *Aleurotrachelus* but differs in the absence of an inner row of marginal teeth and in the absence of the nearly contiguous paramedian processes on the 1st abdominal segment.

KEY TO THE NEW CALEDONIAN SPECIES
(based on pupal cases)

1. Pale species.....*pallida* sp. n.
   Black species 2
2. Without abdominal tracheal comb, margin not sinuate.....*apectenata* sp. n.
   Abdominal tracheal comb present, margin sinuate 3
3. Wide abdominal ridge, no dark-bordered pores laterad on dorsal disc, caudal setae near margin.....*sinuata* sp. n.
   Narrow abdominal ridge, 2 dark-bordered pores laterad on abdomen and on thorax, caudal setae nearer apex of orifice than to margin.....*simila* sp. n.

Leucopogonella apectenata sp. n.
Fig. 12*a–d*

PUPAL CASE (Fig. 12*a–d*): Length 0.68 mm., width 0.41 mm. Colour black. Shape elliptical, not constricted across thoracic folds or invaginated caudally. Pupal case sunk in raised vitreous wax over which lie 8 ribbons of white

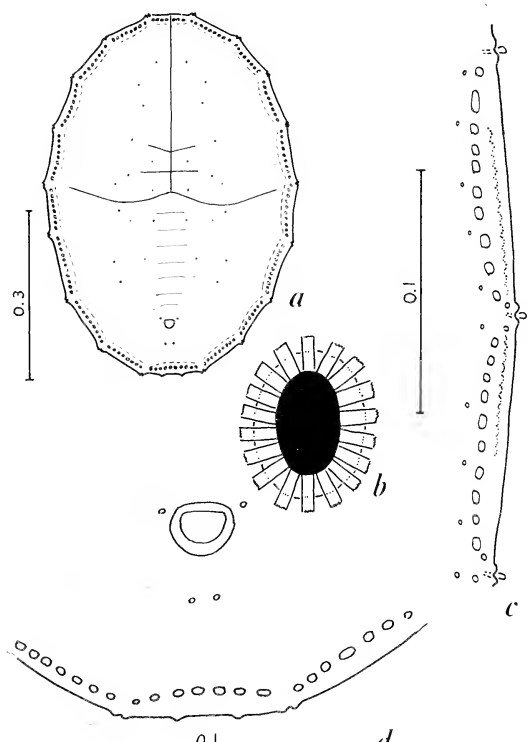


FIG. 12. *Leucopogonella apectenata* sp. n. *a*, Pupal case; *b*, wax fringe; *c*, pupal case, margin; *d*, pupal case, vasiform orifice and caudal margin. (Scale in mm.)

wax (Fig. 12*b*) on each side and single anterior and posterior median ribbons. Margin (Fig. 12*c*) reflexed, obscurely toothed. Apparent margin smooth except for 9 minute paired teeth on each side more or less equidistant, the margin between them straight or nearly so; 4 on the cephalothorax, 5 on the abdomen with the anterior one opposite the end of the transverse moulting suture. Caudal margin with 2 prominences. Submargin not separated from dorsal disc and pigmented to margin. On the submargin is a continuous linear series of contiguous subquadrate pores, about 10 between each pair of marginal processes. The pores tend to be longer than wide. A minute pore mesad of alternate large pores. The line of pores between the processes is slightly concave. The processes are flanked on each side by a smaller pore. Cephalic area with pores as in figure. Meso- and metathorax each with 2 pairs of double pores, one larger and one smaller. Thoracic tracheal folds, pores, and combs absent. Lateral arms of transverse moulting suture nearly straight, meeting in very obtuse median angle. Abdomen, pores on first abdominal segment wide apart in same line as 2 pores on each side at mid-length, paramedian pores on second segment, 8th segment seta bases separated from orifice and level with its anterior margin. Vasiform orifice (Fig. 12*d*) semicircular or broadly cordate, wider than long. Operculum fills orifice. Lingula short included, parallel-sided apex rounded. Distance between caudal seta bases about half width of orifice, bases nearer apex of orifice than to margin. Abdominal tracheal folds, pore, and comb absent.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Tontouta River, coll. L.J.D., 27/4/53.

FOOD PLANT: *Leucopogon* sp.

Leucopogonella pallida sp. n.
Fig. 13*a–c*

PUPAL CASE (Fig. 13*a–c*): Length 0.78 mm., width 0.42 mm. Colour white or colourless. Shape elongate-ovate with an anterior median prominence (Fig. 13*b*), without indentations in thoracic pore area. Margin crenate, scarcely toothed. Submargin defined by submarginal line. On the submargin a linear series of contiguous pores broader than long except in cephalic area, broken by 9 processes or openings, 5 on the cephalothorax and 4 on the abdomen. Pores as in figure. Most prominent are 2 submarginal pores on posterior half of thorax. Thoracic tracheal fold, pore, and comb absent. Thorax with a median ridge obscurely tuberculate and diminishing in width anteriorly. Abdomen with slight median ridge faintly outlined by minute tubercles. First segment without evident setae or pores. Segment 7 longer than 6. Eighth abdominal segment setae minute, slightly anterior

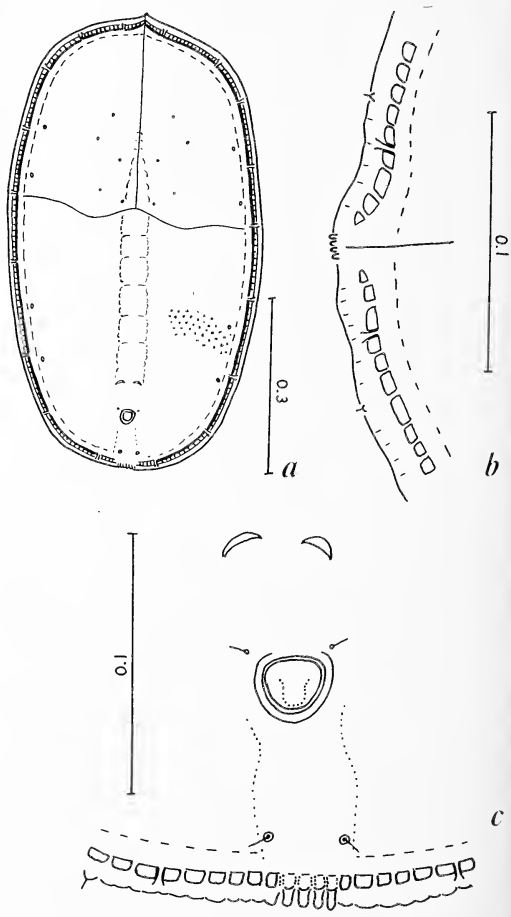


FIG. 13. *Leucopogonella pallida* sp. n. *a*, Pupal case; *b*, pupal case, anterior margin; *c*, pupal case, vasiform orifice and caudal margin. (Scale in mm.)

to orifice, and distant from it. Vasiform orifice (Fig. 13*c*) subcordate, not notched posteriorly but contoured posteriorly by a semicircular line. Operculum subcordate, filling orifice. Lingula short, rounded apically. Caudal setae minute, bases as wide apart as those of the 8th abdominal setae. Two lateral discal pores on each side opposite segments 5 and 7. Dorsal disc, especially between abdominal ridge and submargin, beset with subcircular pustules. Abdominal tracheal fold faintly indicated, finely stippled from orifice half way to margin. Abdominal tracheal comb present with 4 to 6 teeth which are longer than wide.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Plum, coll. L.J.D.

FOOD PLANT: *Leucopogon* sp.

This species shows some affinities with *Aleuroparadoxus* Q. & B. and *Pentaleyrodes* Takahashi.

Leucopogonella similа sp. n.

Fig. 14*a–c*

PUPAL CASE (Fig. 14*a–c*): Length 0.89 mm., width 0.57 mm. Colour dark but paler than *sinuata*. Shape elliptical, margin less sinuate than *sinuata*. Margin (Fig. 14*b*) with 9 processes on each side less prominent than in *sinuata*. Between the processes on the submargin are 14 or 15 pores in a linear series. Pores tending to be longer than wide. Disc pores as in figure. Laterad on or near the submargin is a row of minute paired pores. Mesad of these on the abdomen at mid-length is a pair of larger dark-bordered pores and a similar pore laterad on the mesothorax. The abdominal ridge is narrow. Bases of the 8th abdominal setae slightly anterior to orifice and wider apart than the orifice width. Vasiform orifice (Fig. 14*c*) subcordate, similar to that of *sinuata*. The bases of the caudal setae are slightly nearer to the apex of the orifice than the margin and about the same distance apart as the orifice width. Abdominal tracheal fold absent, comb of 8 to 9 teeth whose rounded apices are level with margin.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Plum, coll. L.J.D.

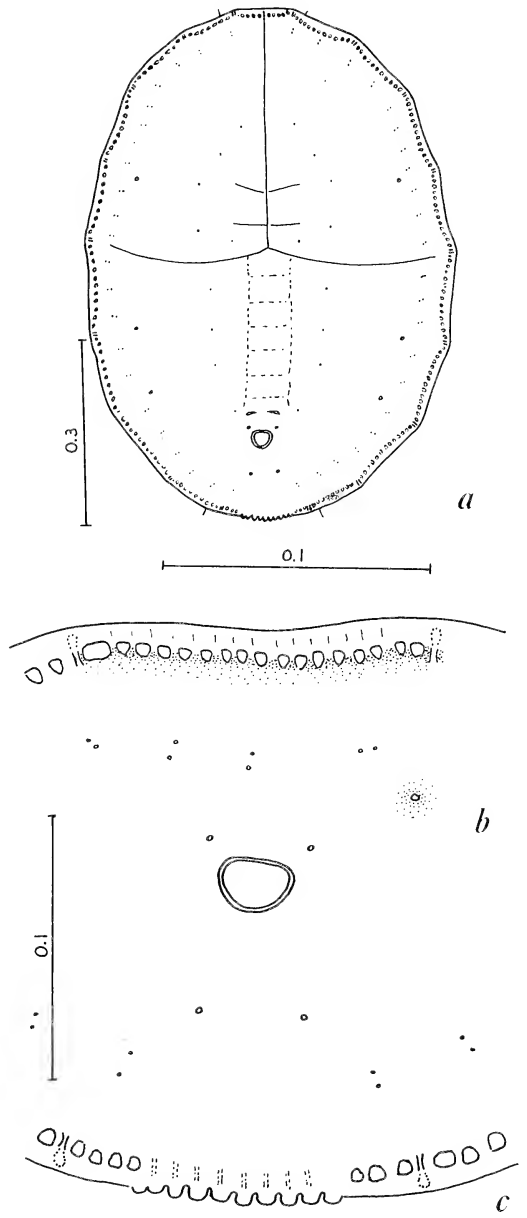


FIG. 14. *Leucopogonella similа* sp. n. *a*, Pupal case; *b*, pupal case, margin; *c*, pupal case, vasiform orifice and caudal margin. (Scale in mm.)

FOOD PLANT: *Leucopogon* sp.

This species occurred on the same food plant with *L. sinuata.*

Leucopogonella sinuata sp. n.
Fig. 15*a, b*

PUPAL CASE (Fig. 15*a, b*): Length 1.0 mm. Width 0.66 mm. Colour black. Shape elliptical. Margin entire or faintly crenulate, sinuate. Submargin distinctly paler than disc but not separated by submarginal line. Margin with 9 processes on each side, concave between these processes. Submargin with continuous linear series of pores. These are pale subcircular or subelliptical areas partly separated by blunt conical black processes of the dorsal disc. About 12–13 pores between processes. A somewhat irregular row of minute pores mesad of the larger linear series. Thoracic area without tracheal folds, pores, or combs. Segments bounded laterally about midway between median line and margin. Abdomen with segments laterally bounded. Eighth abdominal segment with setae bases wider apart than orifice and distant from and slightly anterior to it. Vasiform orifice (Fig. 15*b*) transverse, subcordate. Operculum filling orifice. Lingula. Abdominal tracheal fold absent, tracheal comb present with about 10 teeth, each longer than wide, rounded apically, and somewhat fluted. Caudal seta bases nearer to margin than to apex of orifice, as wide apart as width of orifice.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Plum, coll. L.J.D.

FOOD PLANT: *Leucopogon* sp.

Occurred with *simila* at Plum on the same food plant, and also at Yate, Montagne des Sources, and Mt. Mou.

GENUS *Orchamoplatus* Russell

(Proc. Hawaiian Ent. Soc. 16 (3): 389–410. New name for *Orchamus* Q. & B. preoccupied in Orthoptera.) The following species of this genus were described and keyed in a previous paper (Proc. R. Ent. Soc. Lond. (B)

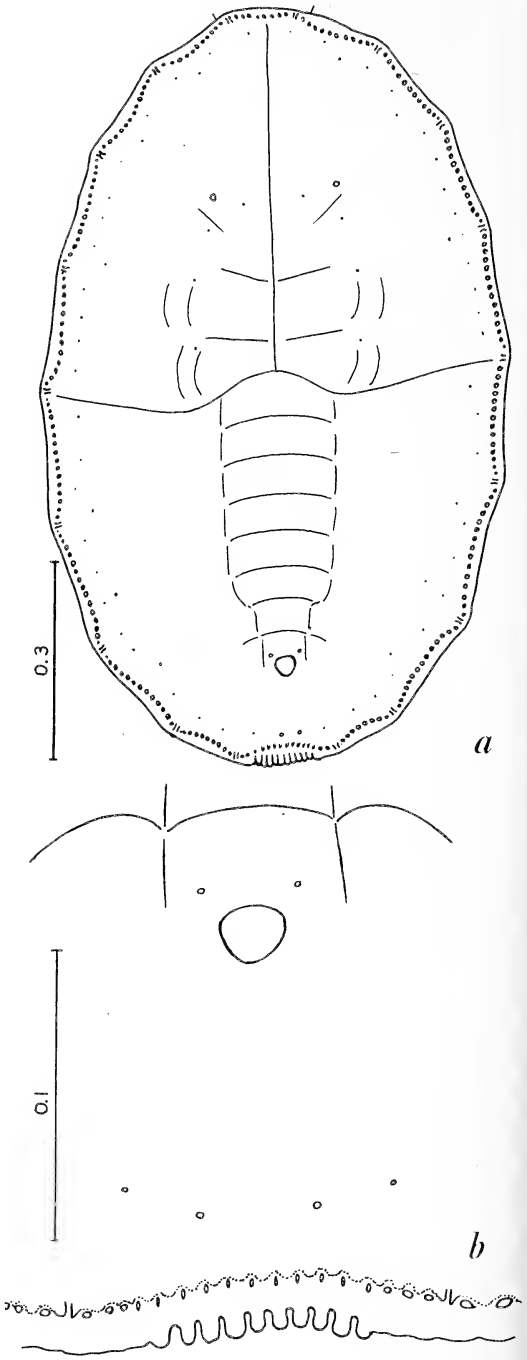


FIG. 15. *Leucopogonella sinuata* sp. n. *a,* Pupal case; *b,* pupal case, vasiform orifice and caudal margin. (Scale in mm.)

25, pts. 7–8, pp. 131–141, 1956): *caledonicus* Dumbleton, *dentatus* Dumbleton, *incognitus* Dumbleton, *montanus* Dumbleton, *plumensis* Dumbleton, and *porosus* Dumbleton. Russell described another species, *O. noumeae,* from citrus in New Caledonia and keyed the existing species of the genus, which include *O. calophylli* Russell from Tonga.

Orchamoplatus perdentatus sp. n.
Fig. 16*a–c*

PUPAL CASE (Fig. 16*a–c*): Length 0.95 mm., width 0.79 mm. Colour black. Widest slightly behind mid-length, flat subcircular, deeply constricted across thoracic combs. Margin with teeth prominent, rounded, as long as wide. Submarginal line distant from margin, meeting and continuous with transverse moulting suture on each side and together completely enclosing the cephalothoracic area. Submargin with a single row of papillae, about 18 anterior to the thoracic tracheal comb and 37 posterior to it on each side. Eye spots triangular, distant from submarginal line. Thoracic tracheal fold not indicated, comb (Fig. 16*b*) with about 6 teeth which are more rounded apically than in *dentatus.* First abdominal segment with a pair of setae and the usual paramedian pores on segments 2 to 5. Segment 6 with 1 pair of specialised papillae identical with those on the submargin. Eighth abdominal seta on tubercles about mid-length on rim of orifice. Vasiform orifice (Fig. 16*c*) subcircular, 0.07 mm. long, slightly transverse. Operculum filling orifice. Lingula not visible. Caudal setae 0.05 mm. long. Abdominal tracheal fold faintly indicated, comb with 6 or 7 teeth, separated, rounded apically.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

TYPE LOCALITY: New Caledonia, coll. F. Cohic.

FOOD PLANT: Undetermined.

The unique specimen is distinct. *O. citri* Takahashi, the only other species with papillae on the disc of the dorsum, has several papillae laterad on the abdomen and is pale in colour. The species is separable from *O. dentatus* Dumbleton by the following characters: more cir-

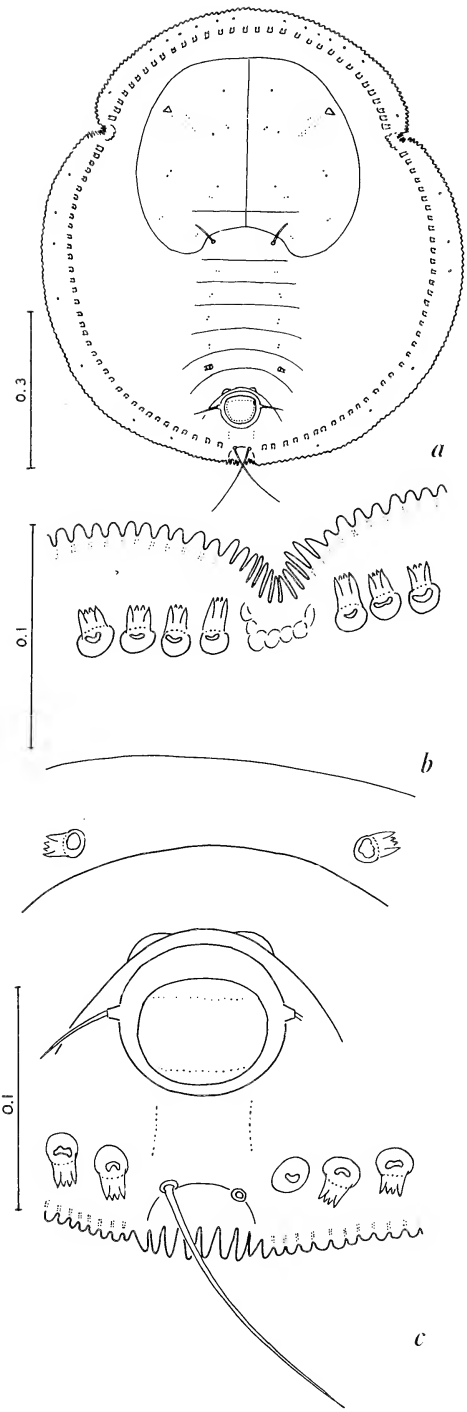
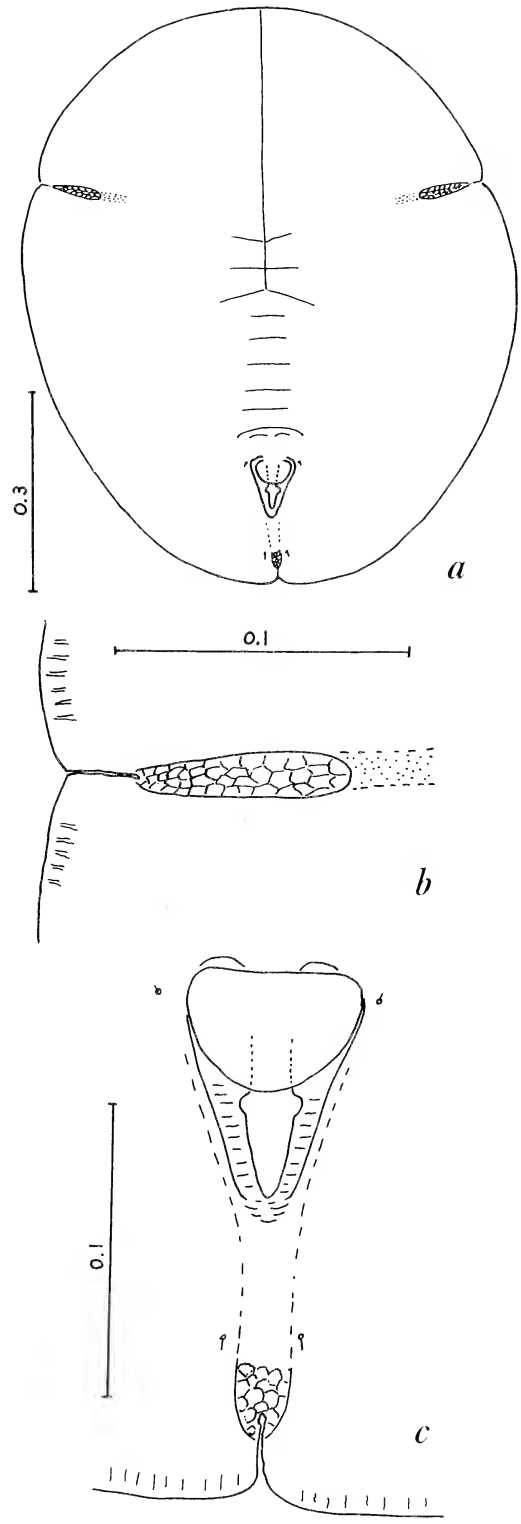


FIG. 16. *Orchamoplatus perdentatus* sp. n. *a,* Pupal case; *b,* pupal case, thoracic tracheal pore and comb; *c,* pupal case, vasiform orifice and caudal margin. (Scale in mm.)



cular shape, more broadly rounded anteriorly, more numerous submarginal papillae especially on abdomen, cephalothoracic area completely enclosed by submarginal line and transverse moulting suture, 2 papillae on the 6th abdominal segment, eye spots distant from submarginal line, suture between 7th and 8th abdominal segments and pockets very close to anterior margin of vasiform orifice. In this latter character the species resembles *plumensis* Dumbleton.

GENUS *Parabemisia* Takahashi

Parabemisia reticulata sp. n.
Fig. 17*a–c*

PUPAL CASE (Fig. 17*a–c*): Length 1.0 mm., width 0.78 mm. Colour transparent or white. Shape elliptical or subcircular, flat, constricted between thoracic clefts, caudal cleft invaginated. Margin with teeth absent but with short narrow ridges immediately mesad of the margin. Anterior and posterior marginal setae present. Submargin not defined. Segmentation as in figure. Thoracic tracheal combs absent, clefts present. Pore (Fig. 17*b*) inset from margin, opens into tracheal fold which is hexagonally reticulate for half its length. The reticulated area is somewhat variable, sometimes longer and expanded mesally. Abdomen without setae on 1st segment, 7th segment shorter than 6th and 8th. Eighth abdominal setae minute, close to anterior lateral margin of orifice. Vasiform orifice (Fig. 17*c*) longer than wide, subtriangular but rounded apically, floor with 8–9 subparallel transverse ridges. Operculum sub-semicircular, wider than long, less than half as long as orifice, more than half length exposed with lateral knob at base of exposed part on each side. Caudal setae small, midway between apex of orifice and margin. Abdominal tracheal cleft and pore similar to thoracic, fold reticulate for only a short distance cephalad.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

FIG. 17. *Parabemisia reticulata* sp. n. *a,* Pupal case; *b,* pupal case, thoracic tracheal pore; *c,* pupal case, vasiform orifice and caudal margin. (Scale in mm.)

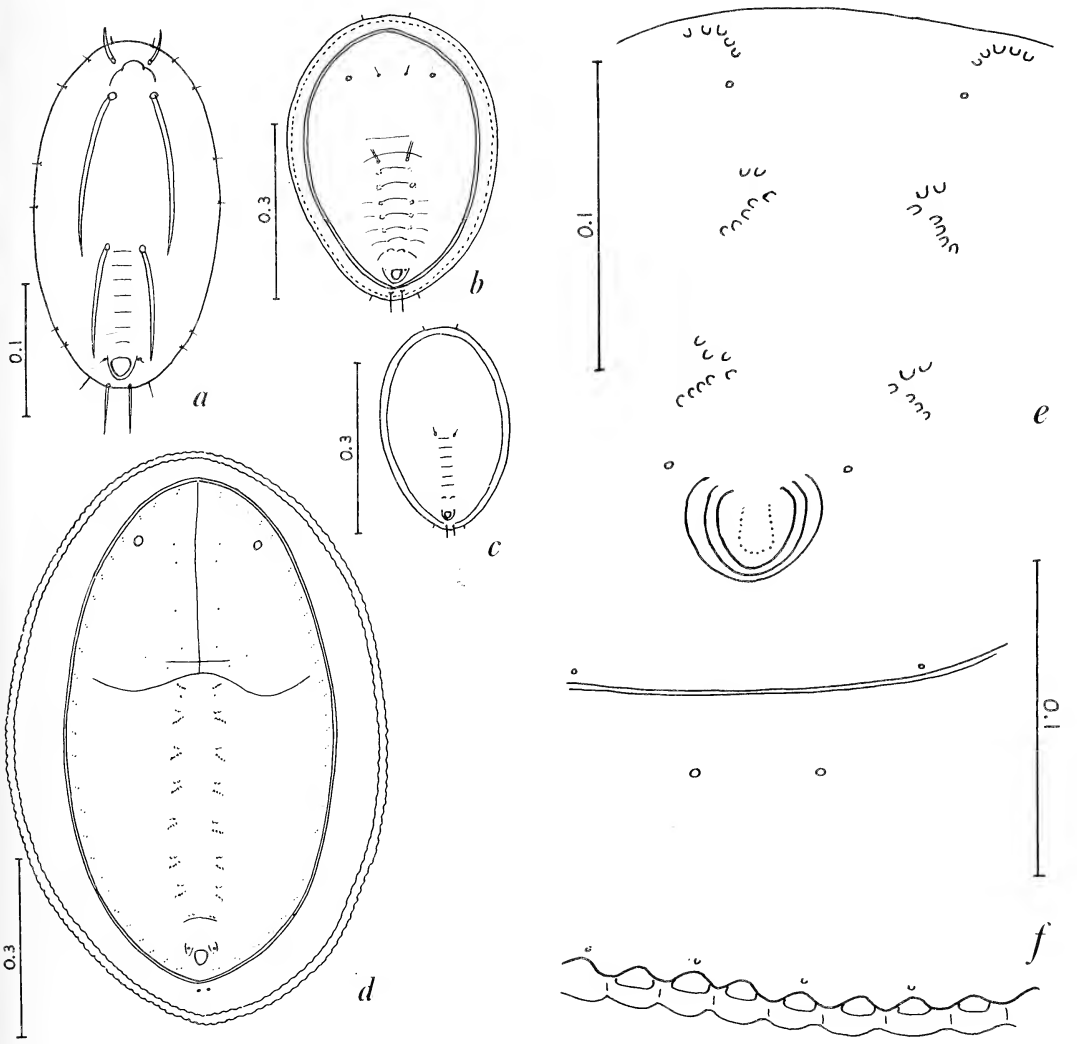


FIG. 18. *Tetraleurodes submarginata* sp. n. *a*, First instar larva; *b*, third instar larva; *c*, second instar larva; *d*, pupal case; *e*, pupal case, abdominal sculpturing; *f*, pupal case, vasiform orifice and caudal margin. (Scale in mm.)

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Montagne des Sources, coll. L.J.D., 17/12/54.

FOOD PLANT: Undetermined.

The facies of this species is that of *Bemisia* but the lateral knobs on the lingula suggest *Parabemisia* and it is placed in that genus, though in the absence of marginal setae and tracheal combs and the presence of tracheal clefts like those of *Dialeurodes* it is not typical.

GENUS *Tetraleurodes* Cockerell

Tetraleurodes submarginata sp. n.
Fig. 18*a–f*

LARVA. First instar (Fig. 18*a*): Length 0.24 mm., width 0.13 mm. Colour pale. Shape elongate-elliptical. Submargin with 6 short setae on each side. Cephalic area with a raised median prominence and 2 short spines anterior to it; cephalic spines long, reaching to first abdominal

segment. Spines on first abdominal segment long, reaching to orifice. Caudal spines as long as anterior cephalic spines.

Second instar (Fig. 18*c*): Length 0.39 mm., width 0.21 mm. Colour pale. Shape elongate-elliptical, slightly tapering posteriorly. Margin crenulate. Inner row of teeth faint or absent. Submarginal line present. Caudal setae and first abdominal setae present.

Third instar (Fig. 18*b*): Length 0.70 mm., width 0.52 mm. Colour light brown, submargin darker. Shape elongate-elliptical, distinctly tapering posteriorly. Margin with 2 rows of teeth. Transverse moulting suture not evident. Processes on first abdominal segment thick and long. No sculpturing evident on abdominal segments.

PUPAL CASE (Fig. 18*d–f*): Length 1.1 mm., width 0.72 mm. Colour black. Shape elliptical, convex. Margin toothed with 2 rows of teeth. Outer row longer than wide, rounded apically, dark brown or black. Submargin wide, sharply defined by groove which contours the margin completely. On submargin mesad of inner teeth are small circular dots behind alternate teeth. Anterior and posterior marginal setae present, short. Submargin in cephalothoracic region with 4 larger pores on each side abdomen with 2 such pores on each side posteriorly at mid-length. Cephalic region with subcircular eye spots and 1 pair short paramedian setae. Pores on cephalothorax as in figure, many paired, especially laterad. Thoracic tracheal folds, pores, and combs absent. Abdomen, first segment with 1 pair of short paramedian setae and with toothed sculpturing (Fig. 18*e*) anterior to base of each seta. Segments 2–7 with similar sculpturing and with paramedian pores. Paired pores laterad on disc and adjoining submarginal line. Eighth segment with seta bases distant from and anterior to orifice. Vasiform orifice (Fig. 18*f*) subcordate, not toothed, slightly raised. Operculum subcordate, filling orifice. Lingula not discernible. Caudal setae on submargin, long, projecting beyond margin, bases as wide as orifice. Abdominal tracheal fold, pore, comb, and anal furrow absent.

HOLOTYPE: Pupal case on slide mount. Deposited in Institut Français d'Océanie, Noumea, New Caledonia.

PARATYPES: In author's collection.

TYPE LOCALITY: New Caledonia, Dothio, coll. F. Cohic.

FOOD PLANT: Undetermined (? *Eugenia*).

This species would run to *Hempelia* Sampson & Drews in Sampson's key but is unlike that genus. In facies it is a *Tetraleurodes* with 2 rows of marginal teeth, or an *Aleurotrachelus* with a submarginal groove.

The Ascidians of Point Barrow, Alaska, Part I
Suborder Phlebobranchia (Enterogona)

DONALD P. ABBOTT[1]

DURING THE YEARS 1948 to 1951 sizeable collections of ascidians were made by workers at the Arctic Research Laboratory, Point Barrow, Alaska. Most of the specimens were dredged during the summers of 1948 to 1950 under the supervision of Professor G. E. MacGinitie of the California Institute of Technology, in the course of an extensive survey of the distribution and ecology of the marine invertebrates of Point Barrow.[2] This material was forwarded to me for study through the kindness of Professor MacGinitie and of Drs. Paul Illg and Fenner A. Chace, Jr., of the Smithsonian Institution, U. S. National Museum. Additional small collections of ascidians were made in 1950–1951 by Dr. Ira L. Wiggins and Mr. James Böhlke of Stanford University; these have been made available to me by Miss Margaret Storey of the Natural History Museum, Stanford University. It is a pleasure to express my thanks to those named above.

A general account of the environment and marine invertebrate fauna of Point Barrow is now available (MacGinitie, 1955). This gives complete locations and descriptions of dredging stations 1–62 (MacGinitie, 1955: 60–85, fig. 1), and includes some information on the distribution and ecology of the ascidians (pp. 180–183). The ascidian names used by MacGinitie are based on determinations made by myself. McGinitie's locality records are more comprehensive than those included here, for he has listed some records resulting from field identifications (using determined comparison specimens) of material which was not preserved for later study. In the present systematic account I have cited only specimens which I have examined personally.

The collections contained 27 ascidians belonging to the suborder Phlebobranchia, representing 3 species: *Ascidia callosa, Chelyosoma macleayanum,* and *C. inaequale.* The first 2 species are familiar arctic forms; while well known, much remains to be learned of their variability. *C. inaequale* is previously known only from 10 specimens, plus three very dubious records from deep water off southern California and Panama (Van Name, 1945: 209). Collecting data on the material examined are listed in Table 1.

In the following section the references listed are limited to a few earlier works which have made important contributions or which contain good descriptions or extensive bibliographies on the species concerned. The descriptions given are intended to supplement, not duplicate, the existing accounts cited for each species.

ORDER ENTEROGONA
SUBORDER PHLEBOBRANCHIA
FAMILY ASCIDIIDAE

Ascidia callosa Stimpson, 1852

Ascidia adhaerens Ritter, 1901, pp. 227–230, pl. 27, figs. 1–5.

A. (Ascidiopsis) columbiana Ärnbäck, 1934, pp. 53–55, text figs. 13–14.

A. callosa Hartmeyer, 1924, pp. 41–53; Huus, 1930, pp. 1–11, figs. 1–6; Ärnbäck, 1934, pp. 49–52, pl. 4, 6, figs. 19–26, 43–44, text fig. 12; Van Name, 1945, pp. 178–180, pl. 4, fig. 5, text figs. 92–94.

Ascidiopsis columbiana Huntsman, 1912, pp. 110–113, pl. 10, fig. 5, pl. 14, figs. 5, 7, 8.

DESCRIPTION: The following notes supplement the description given in Van Name

[1] Hopkins Marine Station of Stanford University, Pacific Grove, California. Manuscript received October 12, 1959.

[2] Supported by funds from the Office of Naval Research, Contract and Task Order no. N6-onr 24316, Project no. NR 162 911.

TABLE 1

COLLECTING STATION DATA ON PHLEBORANCHIATE ASCIDIANS EXAMINED
Stations 20–61 were occupied by MacGinitie, stations B51–31 to B51–33 by Böhlke

STATION NUMBER	DATE	DEPTH (ft.)	TYPE OF BOTTOM AND REMARKS (after MacGinitie, 1955)	SPECIMENS EXAMINED		
				Ascidia callosa	*Chelyosoma macleayanum*	*Chelyosoma inaequale*
20	9 Sep 48	125	stones (sea urchins, *Psolus*, sea anemones)	3		
23	15 Sep 48	130	stones (sea anemones, *Psolus*, sea urchins)		3	
26	9 Aug 49	130	stones, gravel			1
27	9 Aug 49	420	stones, gravel	1		1
32	17 Aug 49	741	mud (worm tubes)	1		
36	6 Sep 49	477	few rocks (worm tubes)		1	
37	6 Sep 49	227	stones, large perforated rocks		4	
42	6 Oct 49	216	rocks, stones (*Psolus*, sea urchins)	2		
44	11 Oct 49	453	rocks, stones, small amount of gravel (*Psolus*)	1	2	1
45	11 Oct 49	341	stones, gravel, few rocks (sea urchins)		1	
61	5 Aug 50	204	mud, stones, gravel	1		
B51–31	29 Jul 51	151			1	
B51–32	29 Jul 51	164			2	
B51–33	29 Jul 51	144			1	

(1945). Tunic highly variable with size, age, and environment; in smaller specimens less than 1 mm. thick, membranous, colorless, transparent, smooth or slightly tuberculate, sometimes papillate about the apertures; in larger individuals up to 9 mm. thick, gelatinous to cartilaginous, dirty tan to olive brown, often wrinkled and encrusted with debris. Siphons ranging from very short to nearly one-third of the total body length. Oral aperture with 6–8 lobes, atrial with 6 lobes; some individuals with orange pigment spots between adjacent lobes on both siphons. Tentacles of 3 or 4 sizes, variable in number (Table 2), and regular to irregular in arrangement. Dorsal tubercle usually with a U-shaped slit, the opening sometimes canted toward the left; horns of the slit conspicuously outrolled in the largest specimen examined (sta. 44). Internal longitudinal vessels variable in number (Table 2), bearing both regular and intermediate papillae (the latter often irregularly distributed). Transverse vessels of 5 orders present in larger specimen from sta. 42, the smallest order being parastigmatic, irregularly distributed, incompletely developed, and corresponding in position to the intermediate papillae of the internal longitudinal vessels. Stigmata 2–20 per mesh. Renal vesicles forming a conspicuous layer of small bladders, particularly on the gut and adjacent mantle on the left side. Gonads well developed only in the 3 specimens from sta. 20 (1 specimen, only 11 mm. long, bore a single row of large eggs in its oviduct), all of these with developing larvae in the atrial chambers.

DISCUSSION: This species has often been confused with *Ascidia obliqua* and *A. prunum*, which also occur in arctic waters. It differs from *A. obliqua* in bearing intermediate papillae on the internal longitudinal vessels and in its possession of abundant renal vesicles. It is distinguished from *A. prunum* most conspicuously by its much smaller number of internal longitudinal vessels and by its habit of brooding

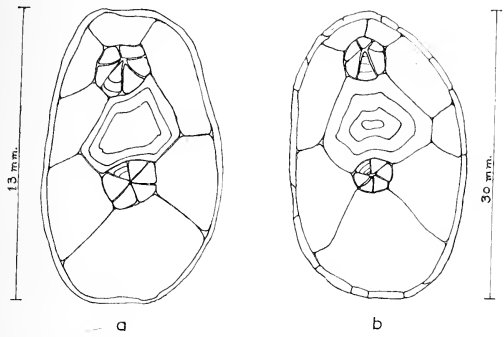


FIG. 1. *Chelyosoma macleayanum.* Dorsal view of disc; growth lines indicated only on intersiphonal plate and two siphonal plates. *a,* Individual with 7 marginal plates; *b,* individual with 8 marginal plates.

embryos and immature larvae within the atrial cavity.

The tentacle counts for the 4 largest specimens (Table 2) are higher than those usually obtained in *A. callosa,* although Ärnbäck (1934: 53) records similar numbers. The difference here is probably not significant. Tentacle counts vary a good deal depending on the degree of development of a fourth cycle of very small tentacles; in the present study these tentacles were counted when present, whereas earlier workers have often ignored or overlooked them in making counts.

The specimen from 741 ft. (123 fathoms) represents an unusual depth record for the species; Van Name (1945: 180) indicates a maximum depth for *A. callosa* of about 80 fathoms.

DISTRIBUTION: Norway, N. Ireland (?), the Faeroes, Iceland, Greenland, eastern N. America south to Cape Cod, arctic N. America, western N. America south to Puget Sound, Bering Sea, and Korea.

FAMILY RHODOSOMATIDAE

Chelyosoma macleayanum Broderip & Sowerby, 1830

Fig. 1*a, b*

Chelyosoma macleayanum Huntsman, 1921, pp. 27–33, pl. 1, fig. 1, text fig. 1; Hartmeyer, 1924, pp. 2–9, text fig. 36; Ärnbäck, 1934, pp. 76–84, pl. 5, figs. 27–33; Van Name, 1945, pp. 205–207, text fig. 118.

DESCRIPTION: The following notes supplement the description of Van Name (1945). Dorsal disc of test divided into plates arranged as follows: 6 triangular plates forming a ring about each aperture; remainder of disc bearing 1 central intersiphonal plate and 7 or 8 marginal plates, the 8th marginal plate, when present, occupying an asymmetric position to the right of the center of the intersiphonal plate (Fig. 1); lateroventral plates below rim of disc

TABLE 2

Ascidia callosa

STATION NUMBER	DIMENSIONS (mm.)	ORAL LOBES	ATRIAL LOBES	TENTACLES	INTERNAL LONGITUDINAL VESSELS		
					Right	Left	Total
20	11× 6× 1*	8		32	19–20	16	35–36
27	14× 9× 4	8	6	24			
20				26	19	14	33
42	14×10× 4	8	6				
61	16×16× 5	7	6	70†	20	16	36
32	33×24×12	7	6	ca. 50	18	16	34
42	41×28×13	6	6	ca. 65	17–18	19	36–37
44	75×53×35			ca. 55	26	23	49

* Measured on animal removed from tunic; all other size measurements in table made on intact animal in tunic.
† Fourth order tentacles unusually numerous.

TABLE 3

Chelyosoma macleayanum

STATION NUMBER	LENGTH OF DISC (mm.)	NUMBER OF MARGINAL PLATES ON DISC	NUMBER OF GROWTH LINES ON PLATES OF DISC
23	—	7	—
23	—	7	—
36	3	8	0
23	7	8	—
44	8	7	2
37	8	8	2
44	8.5	7	2
B51–32	10	8	2
37	11	8	2
45	12	8	2
B51–33	12	8	2
B51–32	13	7	2
37	14	8	1?
37	17	8	3
B51–31	30	8	3

indistinct or absent except in largest specimen (disc 30 mm. long); 0–3 growth lines present on plates of disc. Quantitative information is presented in Table 3.

DISCUSSION: All of the specimens of this well-known arctic species obtained at Point Barrow are assigned to the form *typica* (Ärnbäck, 1934), which is characterized by possession of a single central intersiphonal plate and 5–9 marginal plates. Van Name (1945) considers the individuals with 7 more or less symmetrically placed marginal plates (Fig. 1*a*) to represent the normal condition, and this appears to be the case in northern Atlantic waters, but Ärnbäck has described a population from Pitlekaj on the Siberian arctic coast (67° 7′ N., 173° 24′ W.) in which the modal number of marginal plates is 8, the 8th plate being located on the right as in the Point Barrow specimens. The sparse comparative data available (Table 4) suggest a zoogeographic cline with respect to number of marginal plates, and a re-examination of earlier collections of *C. macleayanum* with this possibility in mind should prove worthwhile.

Growth lines on the test plates show a general increase in number with the size of the animal (Table 3), and suggest that the largest individuals taken were in their 4th year (see Huntsman, 1921).

DISTRIBUTION: Circumpolar arctic: Russia, Norway, Iceland, Greenland, eastern N. America south to Cape Ann, arctic N. America, Bering Strait, Sea of Okhotsk, Siberian arctic.

Chelyosoma inaequale Redikorzev, 1913
Figs. 2, 3*a–e*

C. inaequale Redikorzev, 1913, pp. 206–208, fig. 2; Ärnbäck, 1934, pp. 80–81; Van Name, 1945, p. 209.

DESCRIPTION: Body elongate-oval, the dorsal surface flattened to form an oval disc bearing the siphons and surrounded by a marginal ridge whose prominence varies with degree of body contraction. Both apertures 6-lobed. Tunic tough, flexible, translucent, grey-white to yellowish, locally thickened to form triangular plates on all siphon lobes (Fig. 3*b*) and a conspicuous array of warts, ridges, and small plates on the disc and marginal ridge, giving the dorsal surface a tesselated appearance (Figs. 2, 3*a*). Internal surface of tunic bearing a ridge below

FIG. 2. *Chelyosoma inaequale.* Dorsal view of disc.

TABLE 4

Chelyosoma macleayanum, PER CENT OF POPULATION BEARING SPECIFIC NUMBERS OF MARGINAL PLATES

REFERENCE AND LOCATION	NUMBER OF SPECIMENS EXAMINED	NUMBER OF MARGINAL PLATES					
		5	6	7	8	9	Uncertain
		%	%	%	%	%	%
Hartmeyer, 1924; material mostly from Greenland	53	2	9	79	2	0	8
Present collections; Point Barrow, Alaska	15	0	0	33	67	0	0
Ärnbäck, 1934; material from Siberian arctic, mostly Pitlekaj	185	0	0	11	87	2	0

each siphonal plate and numerous papillae dorsally and dorsolaterally to which mantle muscles attach. Mantle thin, with muscles strongly developed about the siphons and below the marginal ridge of the disc but nearly absent elsewhere. Tentacles simple, of 2–4 orders (Table 5). Dorsal tubercle with a crescentic slit (Fig. 3*c*); 20–40 dorsal languets of 1 or 2 sizes (Fig. 3*c*; Table 5). Pharynx relatively complex and thick-walled (Fig. 3*d*); 18–31 internal longitudinal vessels on each side, often interrupted, where incomplete their position being marked by papillae; transverse vessels irregularly branched, in places forming a perforated sheet medial to the stigmata; stigmata scattered, varying from oval slits to spiral infundibula, exhibiting complex anastomoses with other pharyngeal structures; external pharyngeal wall in places provided with branching bundles of muscle fibers. Anal margin lobulate (Fig. 3*e*). Gonads situated in the intestinal loop and ramified over most of the inner and outer surfaces of the intestine.

DISCUSSION: This remarkable species is known with fair certainty only from Redikorzev's original material (7 specimens, Sea of Okhotsk) and from 3 small individuals from Teller and Point Hope, Alaska, reported by Van Name (1945). It differs from all other members of the genus in lacking a clear series of dorsal plates arranged with fair geometrical regularity and precision, the test instead being relatively smooth or dotted with scattered thickenings and protuberances. The latter are especially well developed in the present specimens, and, while irregular, do sometimes suggest a crude pattern consisting of a central intersiphonal plate (divided in the median sagittal

TABLE 5

Chelyosoma inaequale

STATION NUMBER	DIMENSIONS OF TEST (mm.)			NUMBER OF TENTACLES	DORSAL LANGUETS	INTERNAL LONGITUDINAL VESSELS	
	L	W	Ht			Right	Left
26	20	10	19	ca. 36 of 1st 2 orders; ca. 39 of 3rd and 4th orders	22, of 2 sizes	19	18
44	25	16	20	ca. 58 of 1st 2 orders; ca. 55 of 3rd order; 4th order very small, numerous, and irregularly placed	20	19	19
27	45	35	18	ca. 58 of 1st 2 orders; few scattered smaller tentacles	40	28–31	20–22

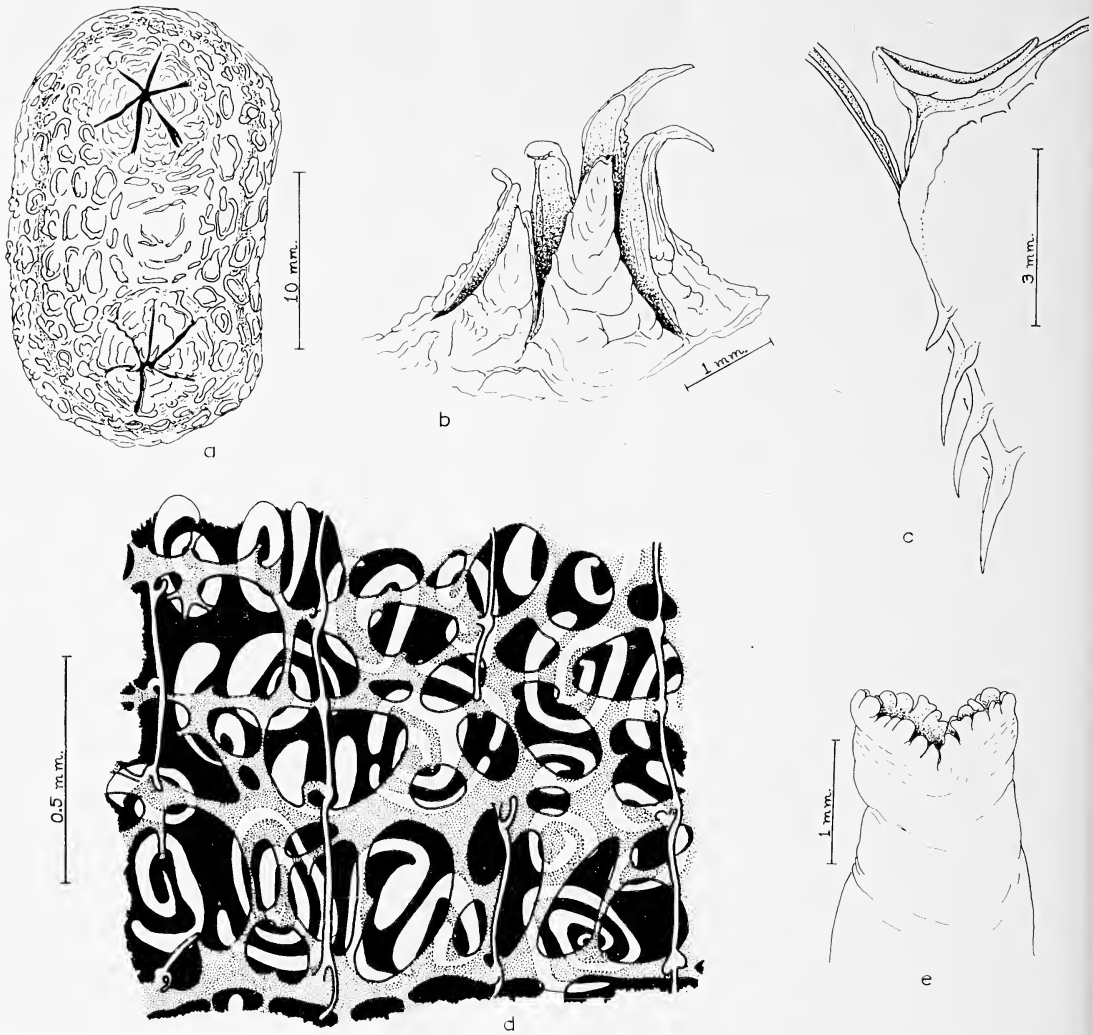


FIG. 3. *Chelyosoma inaequale. a,* Dorsal view of disc; *b,* oral siphon from anterior left side; *c,* dorsal tubercle and anterior dorsal languets; *d,* small area of pharynx, viewed from interior; *e,* anal margin.

plane in the largest specimen) flanked by 2 or 3 rows of peripheral plates. Internally the specimens agree favorably with Redikorzev's account, particularly in the unusual complexity of the pharyngeal wall. The only previous figure of the species is Redikorzev's sketch of the entire animal, which shows few details.

DISTRIBUTION: Sea of Okhotsk, west coast of Alaska off Teller and Point Hope (but see Van Name, 1945).

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The Anatomy of *Coluber radiatus* and *Coluber melanurus*

R. A. M. Bergman[1]

Coluber radiatus is a well-known snake in Java. However, we found only 43 of these in a total of nearly 6,000 snakes collected over a number of years before and after World War II in the north coast of Java. Looking at the small number of *Coluber radiatus* in our catches, one may get the impression that it may be much less common than was generally thought.

The name *radiatus* is explained by Schlegel (1837: 135) as referring to the very typical black stripes on the head and on the sides of the body:

L'occiput est marqué d'une raie transversale noire et un peu en croissant, à laquelle se joignent de chaque côté une raie plus étroite provenant de l'oeil: deux autres, naissant également sur les bords de cet organe descendent sur les lèvres. Le dos est orné de deux larges raies noires longitudinales; une autre plus étroite règne le long des flancs....

The popular name in Java is "ular tikus," meaning the snake (that hunts the) rats, and it is a very apt name, as this snake is indeed a predator on rats and mice and as such is a very useful animal. It is incredibly swift in its movements: we had a *C. radiatus* in a rather small cage, about 100 cm. long and 80 cm. wide and deep, and a rat was put into it. For the first minutes nothing happened, but all of a sudden the snake moved and, in a matter of a few seconds, it caught the rat in a coil, crushing it to death. The whole attack happened so quickly that it was difficult to follow the series of movements involved. This snake is not poisonous and is in no way harmful to man, but it is aggressive, it strikes and bites easily. Sometimes it takes a remarkable attitude more of defense than of attack, as is described by van Heurn (1929), who gives the following details: the first third of the body is bent in a U that points laterally, the head is directed forward towards the enemy, the mouth is wide open. The neck is compressed laterally, contrary to the manner of cobras. The author illustrates his article with a clear drawing.

MATERIALS AND METHODS: Our material consists of 43 snakes, 28 from Surabaia (8 females, 20 males), and 15 from Djakarta (5 females, 9 males, one new-born animal that has not been sexed). Kopstein (1941) measured the length of the body and that of the tail in 15 females and 16 males. In our series we took each animal that was offered, without attempting a selection. The snakes were killed by occipital puncture, weighed, perfused through the aorta with saline followed by Bouins liquid for hardening, and then the distances from the snout to the top and to the end of each organ were measured. For statistical analysis the work of Simpson and Roe (1939) has been followed.

PATHOLOGY: Infestation with round worms was fairly common. Two males (body length 1249 and 1252 mm.) were wounded, the first one at about one-third of its length behind the head, the other one close behind the head.

BLOOD: The blood of a female (body length 1156 mm.) was analysed in the laboratory of Prof. Radsma. The following results were obtained: Na 509, K 18.8, Ca 17.2, where the figures represent the number of mgs. per 100 ml. of plasma.

SIZE: The maximum lengths observed by various authors are summarized, together with our data, in Table 1.

In our material combined with the data gathered by Kopstein, the female group includes six very young animals, hardly more than new-born ones, as against a single very small one in the male group. To make both groups more comparable, the five shortest females are not included in the data used for Figure 1.

For our reasoning it does not make much difference whether we include them or leave

[1] Royal Tropical Institute, Amsterdam. Manuscript received June 8, 1959.

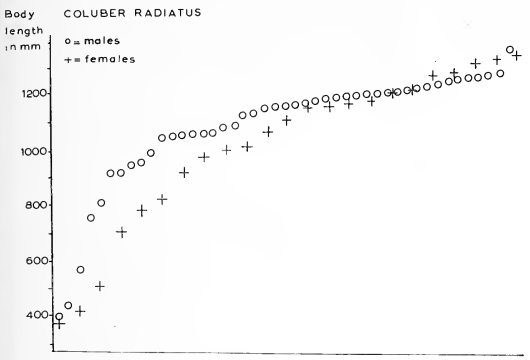

FIG. 1. Body lengths, male and female specimens.

them out, because, in any event, the point of intersection between the first steep part of the curve and the plateau is to be found at a length of about 950 mm. The curve does not suggest a sexual dimorphism in body length.

SEX RATIO: It is always a difficult question whether the findings on a small group can be used in a more general way. In the case of the sex ratio in *C. radiatus,* there are three independent observations, each one on a small group, but all pointing in the same direction. In Table 2 the figures of Kopstein (1938) and those of our material from Surabaia and Djakarta are shown.

These figures are very suggestive of a sex ratio of two males to one female. However, in 1941 Kopstein published a list of measurements on 16 males and 15 females, those of 1938 included. This may signify that a few years more of collecting can change the first impression. On the other hand Kopstein, when collecting, has not included in his method the factor of not-selecting as a *conditio sine qua non,* and it seems probable that his first figure is more the result of a random sample than the second one. But even when we take Kopstein's later figures, there is a greater number of males, still in the order of two males to one female.

MATURITY: In our small series, the shortest female carrying growing eggs (which are 6 mm. in length) has a body length of 1006 mm. As we saw in the curve of successive body lengths (Fig. 1), the intersection of the ascent and the plateau is at about 950 mm. body length. We will not be very far from the real value when we take this figure as the lower limit of the adult size for both sexes.

BODY LENGTH: When all animals are taken together, the average figure for the length of the body is 1096 mm. in males, 898 mm. in females. However, we have already noted that there is an excess of five new-born animals in the female group, which, in a total of 28 animals, makes the average figure too low. If these five females are removed from the series, the average length for the females would be 1018 mm. Taking the adults alone (in this case the animals with a body length longer than 950 mm.), the average length for 38 males is close to 1170 mm., and for 16 females is 1178 mm., which is practically the same figure. It can be

TABLE 1

Coluber radiatus, LENGTH OF BODY AND OF TAIL

AUTHOR	MALES		FEMALES		SEX UNKNOWN	
	Body	Tail	Body	Tail	Body	Tail
de Rooy					1280	330
Smith	1520	370	1445	350		
Kopstein	1267	(293)*	1218	(308)		
Bergman	1380	(311)	1352	308		

* The figures for the length of the tail in parentheses do not refer to the animal whose body length is given.

TABLE 2

Coluber radiatus, SEX RATIO

AUTHOR	MALES	FEMALES	TOTAL
Kopstein 1938	9	6	15
Bergman Surabaia	9	5	14
Bergman Djakarta	20	8	28
Totals	38	19	57

TABLE 3

Coluber radiatus, MUTILATION OF THE TAIL

	TAIL		
	Whole	Mutilated	Totals
Males	35	10	45
Females	24	4	28
Total	59	14	73

TABLE 3*a*

Coluber radiatus, MUTILATION OF THE TAIL

	WHOLE	MUTILATED	TOTALS
Young	17	2	19
Adult	42	12	54
Total	59	14	73

concluded, therefore, that there is no suggestion of sexual dimorphism in body length.

TAIL: For a fighting species the number of broken tails does not seem excessively high: 14 in a total of 73. The figures for both sexes are given in Table 3. One might ask whether the males show more mutilated tails than do the females, or whether it is the other way round, or perhaps whether there is no difference at all.

For the data shown here, χ^2 is very small, and the deviation from the hypothesis of independency is very probably due to chance. In other words, there is no association between frequency of mutilation and sex.

If we should take the young animals of both sexes together and, similarly, the older ones of both sexes, and divide these into groups of mutilated and of nonmutilated individuals, then Table 3*a* will show these new figures. $\chi^2 = 1.24$, and it is not possible to see here an association between the length of life and the number of casualties.

The length of the tail and the body for nonmutilated animals is given in Table 4, and the illustration in Figure 2.

In both sexes the relative length of the tail

TABLE 4

Coluber radiatus, LENGTH OF BODY AND OF TAIL

	N	AVERAGE LENGTH OF THE: Body	Tail	Tail length in ‰ of body length
Males, juv.	6	658	165	250
adult	28	1155	288	252
Female, juv.	6	640	153	239
adult	13	1170	281	240

TABLE 5

Coluber radiatus, THE LENGTH OF THE TAIL IN ‰ OF THE BODY LENGTH

	N	R	$M \pm \sigma n$	$\sigma \pm \sigma\sigma$	$V \pm \sigma v$
Males	28	230–286	251.3 ± 2.3	12.3 ± 1.6	4.9 ± 0.7
Females	13	222–268	240.0 ± 3.4	12.2 ± 2.4	5.1 ± 1.0

is the same in both the group of young and that of the adult animals.

Between the sexes there is a difference which is small but which may well be real: D/σ_D is 2.76. The hypothesis that there is a sexual dimorphism in the length of the tail seems more probable than the alternative.

FERTILITY: Kopstein (1941) reports the observation of van Heurn, who saw 8 eggs in one nest, and adds an observation of his own upon a nest with 10 eggs. Smith (1943) mentions from 5 to 12 eggs laid at a time. In our material, four animals carried mature eggs in the uterus or in the ovaries. The figures are summarized in Table 6.

The average number of eggs per female is about 7, with 5 of them on the right side and 2 on the left.

TOPOGRAPHY: Data on the topographical pattern of the organs are available for 27 male adult animals with an average body length of 1196 mm., and for 9 adult females with an average body length of 1200 mm.

In this case it is already apparent from the average figures that all of the organs are situated more cranially in the female than in the males,

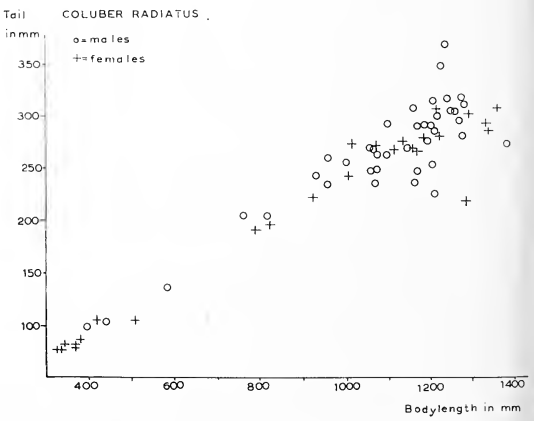

FIG. 2. Body lengths as related to tail lengths.

TABLE 6

Coluber radiatus, NUMBER OF EGGS

BODY LENGTH IN MM.	NUMBER OF EGGS		
	Right	Left	Total
1074	6	3	9
1287	5	2	7
1332	4	3	7
1352	6	—	6
Total n = 4	21	8	29
v. Heurn			8
Kopstein			10
Smith			5
Smith			12
Total n = 8			64

except for the kidneys and the caudal pole of the left ovary, which are situated more caudally in the female. However, to make possible a comparison with other snakes, a table containing the percentile values has been added.

LENGTHS: The lengths of the organs are of the same order in both sexes, except for the gonads: the ovaries are twice as long as the testes. There is some asymmetry: in both sexes the gonads as well as the kidneys are longer on the right side than on the left.

INTERVALS: The intervals between the organs are of the same order in both sexes; in the cranial half of the body they are somewhat greater in the male. In the caudal half the figures are a little higher in the female on the left side. On the right side it is especially B_2, the space between the right gonad and the right kidney, which is greater in females ($D/\sigma_D = 4$). This is due to the fact that the top of the right kidney is more caudally placed in the female (Tables 8, 9). The total amount of free space on both sides is the same in both sexes. However, if we count only the space from the pancreas to the kidney (D_R) on the right side and to that (D_L) on the left side, this region, where the eggs will develop, is greater in females than is the corresponding area in the males, amounting to a difference of about 27 per cent on the right side and 15 per cent on the left.

VARIABILITY: The coefficient of variability (V) is low for all topographical data: it is about 7 in the male series and about 12 in the female.

In the case of the length of the organs, this coefficient is high for the length of the spleen in both sexes and for the length of the gonads

TABLE 7

Coluber radiatus, ♂ ADULTS (> 950 mm.), TOPOGRAPHY

	N	R	M±σm	σ±σσ	V±σv
Body	38	957–1380	1170.0±15.2	94.0±10.8	8.0±0.9
Tail	28	237–351	287.9±4.7	24.6±3.3	8.5±1.1
Heart, top	27	199–264	241.2±2.9	14.8±2.0	6.1±0.8
end	27	231–302	276.8±3.2	16.9±2.3	6.1±0.8
Liver, top	27	286–383	364.3±4.9	25.2±3.4	6.9±0.9
end	27	471–653	580.9±7.2	37.7±5.1	6.5±0.9
Gallbladder, top	27	579–832	708.2±10.1	52.8±7.2	7.5±1.0
end	27	603–859	737.0±10.0	52.3±7.1	7.1±1.0
Pancreas, top	27	604–856	734.2±11.2	58.3±7.9	7.9±1.1
end	27	620–872	751.4±10.2	53.0±7.2	7.1±1.0
Spleen, top	27	601–850	734.2±8.8	53.3±7.2	7.3±1.0
end	27	605–857	737.0±10.2	53.1±7.2	7.2±1.0
Sex R, top	27	688–993	853.6±12.0	62.1±8.5	7.3±1.0
end	27	734–1044	905.3±11.4	59.4±8.1	6.6±0.9
Sex L, top	27	741–1079	931.3±13.1	68.0±9.3	7.3±1.0
end	27	776–1138	975.3±13.3	69.2±9.4	7.1±1.0
Kidney R, top	27	782–1149	990.8±12.9	67.2±9.2	6.8±0.9
end	27	858–1273	1090.9±15.4	80.0±10.9	7.3±1.0
Kidney L, top	27	833–1248	1056.0±14.9	77.4±10.5	7.3±1.0
end	27	917–1331	1150.1±15.6	81.0±11.0	7.1±1.0

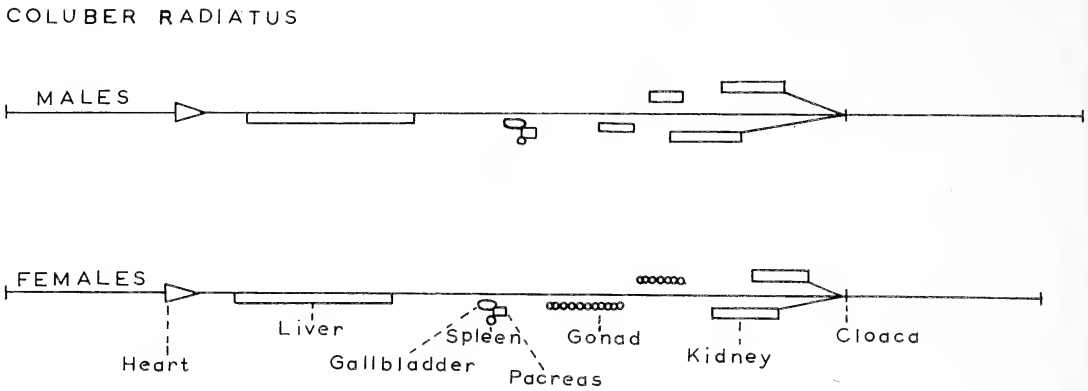

FIG. 3. Topographical pattern of the internal organs in males and females of *Coluber radiatus*.

in the females. For the other organs the range of V is from 10 to 17.

For the intervals the difference seems to be somewhat more marked, the values of V being greater in the female series. However, the small number of females influences the value of σ. Furthermore, the quotient D/σ_D is never higher than 2.5. This figure is found for the variability of C_3 (the distance from the left kidney to the cloaca) in both sexes.

CORRELATIONS: The length of tail has already been discussed above (Table 4). The coefficient of correlation is of the same value in the two sexes. Supporting figures are given in Table 12, both for the symbol r and for its transposition in Z.

The correlation between the length of the body and the weight of the animals seems to be low in the male group. The average weight is of nearly the same value in both sexes. There

TABLE 8

Coluber radiatus, ♀ ADULTS (> 950 mm.), TOPOGRAPHY

	N	R	M±σm	σ±σσ	V±σv
Body	16	989–1325	1175.3±29.0	116.0±20.6	8.4±1.5
Tail	13	247–308	280.4±5.0	17.9±3.5	6.4±1.2
Heart, top	9	195–269	229.5±8.6	28.7±6.8	12.5±2.9
end	9	221–304	263.9±11.5	34.6±8.2	13.1±3.1
Liver, top	9	265–390	324.7±15.0	45.0±10.6	13.8±3.3
end	9	453–653	554.5±23.3	70.0±16.5	12.6±3.0
Gallbladder, top	9	570–765	673.2±25.8	77.1±18.2	11.5±2.7
end	9	596–798	697.7±26.5	79.6±18.8	11.4±2.7
Pancreas, top	9	588–798	695.3±26.6	79.6±18.8	11.5±2.7
end	9	602–816	711.5±27.0	81.4±19.2	11.4±2.7
Spleen, top	9	584–790	689.2±26.4	79.0±18.6	11.5±2.7
end	9	589–798	695.8±26.6	79.6±18.8	11.4±2.7
Ovar. R, top	9	677–902	784.3±25.4	76.1±18.0	9.7±2.3
end	9	738–1023	880.1±33.8	101.5±23.9	11.5±2.7
Ovar. L, top	9	761–1034	902.2±36.0	108.0±25.4	12.0±2.8
end	9	808–1121	977.3±40.0	121.0±28.5	12.4±2.9
Kidney R, top	9	826–1150	1006.4±39.0	117.0±27.6	11.6±2.7
end	9	910–1258	1102.2±43.0	129.0±30.4	11.7±2.8
Kidney L, top	9	874–1186	1063.1±38.6	116.0±27.3	10.9±2.6
end	9	950–1272	1147.2±43.8	131.5±31.0	11.4±2.7

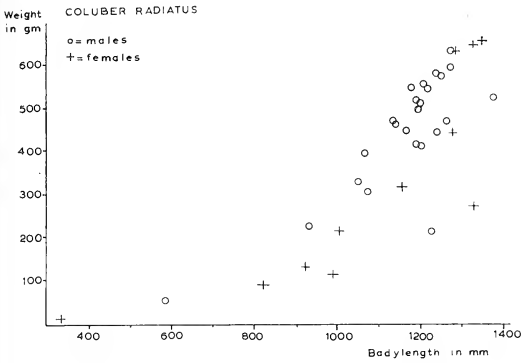

FIG. 4. Relationships between length and weight in males and females.

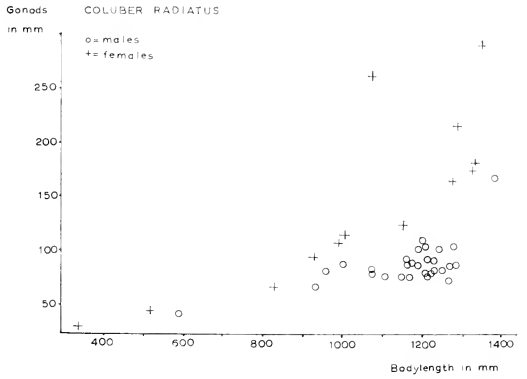

FIG. 5. Length of gonads as related to body length and sex.

TABLE 9

TOPOGRAPHY OF *Coluber radiatus* IN °/₀₀ OF THE BODY LENGTH

♂ ADULTS N = 27		♀ ADULTS N = 9	FEMALES, THE FOLLOWING ORGANS SHIFT IN °/₀₀	
Body length M = 1196		Body length M = 1200	Cranially	Caudally
	°/₀₀	°/₀₀		
Body length	1000	1000		
Tail*	245	234		
Heart, top	202	191	11	
end	232	220	12	
length	30	29		
Liver, top	287	271	16	
end	485	462	23	
length	198	192		
Gallbladder, top	592	561	31	
end	616	582	34	
length	24	22		
Pancreas, top	614	580	34	
end	629	593	36	
length	15	13		
Spleen, top	610	575	35	
end	616	580	36	
length	6	5		
Sex R, top	704	645	71	
end	743	733	25	
length	40	89		
Sex L, top	766	752	23	4
end	803	815		
length	35	63		
Both	74	152		
Kidney R, top	791	840		49
end	876	919		43
length	85	79		
Kidney L, top	850	886		36
end	922	955		33
length	73	69		
Both	157	149		

* Data from the table of correlations.

TABLE 10

Coluber radiatus, ADULTS, LENGTH OF THE ORGANS

	N	R	M±σm	σ±σσ	V±σv
Males > 950 mm.					
body	38	957–1380	1170.0±15.2	94.0±10.8	8.0±0.9
tail	28	237–351	287.9±4.7	24.6±3.3	8.5±1.1
heart	27	30–45	36.0±0.8	4.2±0.6	11.7±1.6
liver	27	185–291	236.8±3.9	20.2±2.7	8.5±1.2
gallbladder	27	22–42	29.4±1.0	5.2±0.7	17.6±2.4
pancreas	27	12–27	18.9±0.6	3.3±0.4	17.5±2.4
spleen	27	4–12	6.9±0.4	2.3±0.3	33.0±4.5
sex R	27	41–61	47.7±1.1	6.1±0.8	12.7±1.7
sex L	27	30–59	41.2±1.4	6.6±0.9	16.0±2.2
sex both	27	76–110	88.8±2.3	11.0±1.5	12.4±1.7
kidney R	27	76–134	105.7±2.9	14.9±2.0	14.1±1.9
kidney L	27	64–112	89.8±2.0	10.4±1.4	11.7±1.6
both kidneys	27	150–232	197.0±1.2	20.2±2.7	10.2±1.4
Females > 959 mm.					
body	16	989–1352	1178.5±29.0	116.0±20.5	8.4±1.5
tail	13	247–308	280.4±5.0	17.9±3.2	6.4±1.3
heart	9	25–41	34.5±1.7	5.2±1.2	15.1±3.6
liver	9	184–287	230.7±11.3	33.1±7.8	14.3±3.4
gallbladder	9	19–33	26.5±1.7	5.0±1.2	19.5±4.6
pancreas	9	12–22	16.2±1.1	3.2±0.8	19.8±4.7
spleen	9	4–9	6.5±0.6	1.7±0.4	26.2±6.2
ovar. R	9	61–174	106.9±13.2	39.6±9.3	37.0±8.7
ovar. L	9	47–117	75.0±8.2	24.6±5.8	32.8±7.7
ovar. both	9	108–291	182.0±23.4	70.0±16.5	38.6±9.1
kidney R	9	71–126	95.7±4.9	16.3±3.9	17.0±4.1
kidney L	9	70–96	83.2±3.0	9.1±2.1	10.9±2.6
both kidneys	9	141–216	178.9±7.9	23.8±5.6	13.3±3.1

TABLE 11

Coluber radiatus, MALE ADULTS, INTERVALS BETWEEN THE ORGANS

	N	R	M±σm	σ±σσ	V±σv
A1 snout–heart	27	199–264	241.2±2.9	14.8±2.0	6.1±0.8
A2 heart–liver	27	43–87	66.3±2.1	11.0±1.5	16.6±2.5
A3 liver–gallbladder	27	95–179	127.3±3.8	19.8±2.7	15.5±2.6
A	27	362–506	435.–±7.5	39.–±5.3	9.–±1.2
B1 pancreas–gonad	27	68–141	101.5±2.7	14.–±1.9	13.9±1.8
B2 gonad R–kidney R	26	38–125	85.6±4.2	20.7±2.8	24.2±3.4
B3 kidney R–cloaca	26	77–120	102.7±2.2	11.–±1.5	10.7±1.5
B	26	215–333	289.2±4.9	25.0±3.5	8.6±1.2
C1 pancreas–gonad L	27	121–208	182.0±3.5	18.–±2.4	9.9±1.4
C2 gonad L–kidney L	26	48–113	82.6±3.4	17.3±2.4	21.2±2.8
C3 kidney L–cloaca	26	39–59	47.6±1.1	5.4±0.8	11.4±1.6
C	26	218–366	311.5±5.8	30.–±4.2	9.6±1.3
A+B	26	577–839	724.3±10.8	55.–±7.6	7.6±1.–
A+C	26	580–872	742.8±12.1	60.9±8.5	8.2±1.1
D_R pancreas–kidney R	26	162–284	232.9±4.7	24.7±3.3	10.6±1.5
D_L pancreas–kidney L	26	213–376	305.5±5.5	30.6±4.3	10.–±1.4

TABLE 12

Coluber radiatus, FEMALE ADULTS, INTERVALS BETWEEN THE ORGANS

	N	R	M±σm	σ±σσ	V±σv
A1 snout–heart	9	195–269	229.5±8.6	28.7±6.8	12.5±2.9
A2 heart–liver	9	36–90	60.8±5.5	16.4±3.9	27.–±5.6
A3 liver–gallbladder	9	60–161	118.4±9.3	27.9±6.6	23.6±5.6
A	9	302–516	398.7±6.3	18.6±4.4	4.7±1.1
B1 pancreas–ovar	9	29–86	62.7±5.8	17.7±4.2	28.2±6.6
B2 gonad R–kidney	9	88–166	126.3±8.7	26.–±6.1	20.6±4.9
B3 kidney R–cloaca	9	73–117	73.8±3.6	10.9±2.6	14.8±3.5
B	9	227–334	28.6±4.1	12.2±2.9	4.3±1.0
C1 pancreas–ovar	9	147–250	190.7±10.8	32.5±2.9	17.1±4.–
C2 ovar. L–kidney L	9	51–118	85.7±6.6	19.9±4.7	23.2±5.5
C3 kidney L–cloaca	9	39–84	53.–±4.8	13.7±3.2	25.6±6.0
C	9	255–409	330.2±17.2	45.5±10.7	13.7±3.2
A+B	9	534–831	694.7±30.7	29.1±6.8	4.9±1.2
A+C	9	592–861	739.–±29.–	27.6±6.5	3.7±0.9
D_R pancreas–kidney R	9	215–365	295.–±14.–	41.8±9.9	14.5±3.4
D_L pancreas–kidney L	9	263–418	351.3±16.–	48.3±11.4	13.8±3.3

TABLE 13

Coluber radiatus, CORRELATIONS

	N	R	M±σm	σ	V
FEMALES					
Body length	6	1006–1352	1200.3±64.0	143.0	11.9
Tail length	6	247–308	280.0±10.2	22.9	8.2
		r = 0.750	Z = 0.96±0.58		
Body length	8	989–1352	1216 ±55.6	148.–	12.2
Weight	8	118–658	426 ±78	206.–	48.5
		u = 0.810	Z = 1.14±0.45		
Body length	9	989–1352	1200.0±51.0	144.–	12.0
Gonads	9	108–291	182.0±22.8	64.5	35.4
		r = 0.740	Z = 0.95±0.41		
Body length	9	989–1352	1200.0±51.0	144.0	12.0
Kidneys	9	141–216	179.0± 8.8	24.8	13.9
		r = 0.750	Z = 0.96±0.41		
MALES					
Body length	29	957–1285	1158.7±18.1	97.6±12.8	8.4±1.1
Tail length	29	237–350	287.4± 4.6	24.7± 3.2	8.6±1.1
		r = 0.760	Z = 1.00±0.20		
Body length	22	1061–1380	1210.6±15.5	72.8±11.0	6.0±0.9
Weight	22	217–635	477.8±21.7	101.7±15.3	21.2±3.2
		r = 0.508	Z = 0.57±0.23		
Body length	27	957–1380	1192.2±15.4	80.0±10.9	6.7±0.9
Gonads	27	76–110	88.8± 1.9	9.9± 1.4	11.1±1.5
		r = 0.410	Z = 0.44±0.20		
Body length	29	957–1380	1201.0±18.3	93.1±12.9	7.6±1.0
Kidneys	26	150–232	196.5± 4.1	20.8± 2.9	10.6±1.5
		r = 0.780	Z = 1.06±0.28		

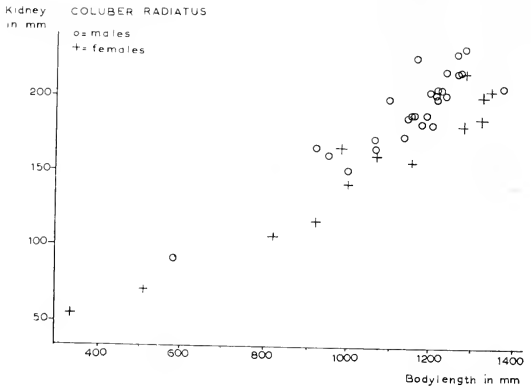

FIG. 6. Length of kidneys as related to body length and sex.

is no sexual dimorphism in this respect.

The coefficient of variation for the length of the gonads is much higher in the small group of females than in the male group; the coefficient of correlation r is lower in the latter.

For the length of the body and that of the kidneys, the values of the coefficients of correlation r are of the same order for both sexes.

Coluber melanurus

Coluber melanurus appears to be widespread (de Rooy, 1916). However, in the vicinity of Surabaia and Djakarta on the north coast of Java this snake is very seldom found: we collected only four of these animals, three males, one female.

Melanurus means "with a black tail." In our specimens not only the black tail is very conspicuous, but the black markings on the sides in the cranial half of the body and the black streaks behind the eye cannot be overlooked.

The maximum size, according to de Rooy, is 1400 + 400 mm. Smith gives 1200 + 360 mm. for a male (*Elaphe flavolineata*). Our specimens are much smaller: they range from 387 to 481 mm. in body length. This would suggest that they are young animals. The female is the shorter one. However, the number of observations is too small to be of any use when the question is put whether or not there is a sexual dimorphism in body length. The length of the tail (in ‰ of the body length) is 242-242-269 in our male animals, and in our female specimen it is 238. So there does not seem to be a sexual dimorphism in this character.

In one of the males, (400 mm. in length), a worm was protruding through the skin, about at the level of the top of the right testis.

TOPOGRAPHY: The measurements and their values (expressed in permillage of the length of the body) are given in Table 14.

In our young female the heart and the liver are placed somewhat more caudally than in the males, which is an unusual though not wholly improbable situation. Another exceptional measurement is that the top of the right kidney is also placed more cranially in this female than in the males. Table 14 shows the relevant figures in brackets. Perhaps an error in recording the data has been made here. Indeed, one would expect the top of the right kidneys in a female animal to be placed a little caudally from the same spot in the male, or perhaps at the same level, but hardly more cranially. Furthermore, as the figures are studied, the length of the right

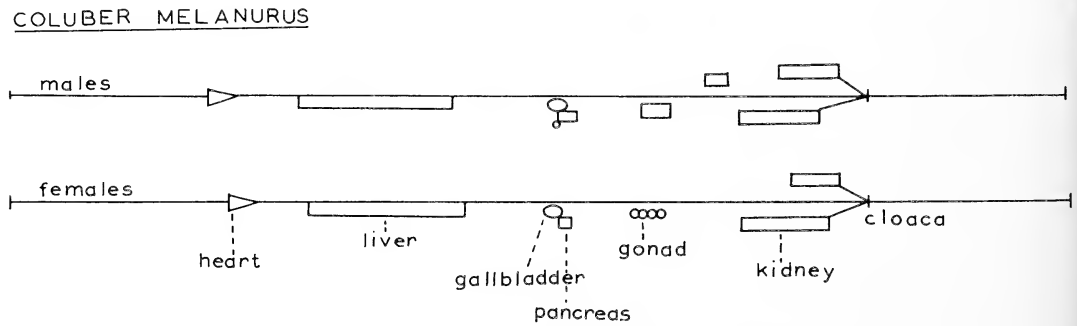

FIG. 7. Topographical pattern of the internal organs in males and a female of *Coluber melanurus*.

kidney seems to be rather long in this female—55 mm.—whereas one would expect it to be about 93 ‰ of the body length, or about 36 mm. If the kidney had really been so much longer than usual, I would certainly have added a memorandum to that effect. If we accept the smaller figure (36 mm.) for the end of the kidney as the correct one, because we find it to correspond with the expected value, this correction would place the top at 331 mm. from the snout instead of at 313, as was recorded. This is probably to be explained as a simple transposition of the figures. Unfortunately the material is no longer available and cannot be checked.

LENGTH OF THE ORGANS: The only difference found between the sexes is the length of the kidneys, and as explained, this is probably a mistake. If we accept the rectification, the length of both kidneys in the female is 64 mm. or, in

TABLE 14

Coluber melanurus

TOPOGRAPHY	MALES						FEMALES			
	Absolute values						‰	Absolute value		‰
	2110		5795		3021	M		5210		
Body	400		429		481	437	1000	387		1000
Tail	97		95		129	107	230	92		238
Heart, top	97		91		113	100	230	99		256
end	112		115		126	117	270	108		256
length		15		24	13	17	40	9		23
Liver, top	134		145		161	147	336	135		349
end	205		216		251	224	513	205		530
length		71		71	90	77	177	70		181
Gallbladder, top	251		268		305	272	629	241		623
end	262		278		311	283	650	249		638
length		11		10	6	9	21	8		21
Pancreas, top	260		272		310	281	643	247		638
end	268		279		318	288	661	253		654
length		8		7	8	7	18	6		16
Spleen, top	258		271		308	279	639	—		—
end	260		273		311	281	643	—		—
length		2		2	3	2	5	—		—
Testes R, top	296		314		355	322	736	281		726
end	311		327		371	336	769	295		762
length		15		13	16	14	34	14		36
Testes L, top	324		344		391	353	809	—		—
end	338		357		402	366	838	—		—
length		14		13	11	13	29	—		—
both		29		26	27	27	63	—		—
Kidney R, top	335		369		410	371	851	[313]		[810]
end	370		408		458	412	944	368		951
length		35		39	48	41	93	[55]		[141]
Kidney L, top	358		385		428	390	895	349		903
end	386		415		465	422	966	375		970
length		28		30	37	32	72	26		67
both		63		69	85	72	165	81		208
Weight	12		14		24	17	38	22		57
Lung, top			108					107		276
opening			—					—		—
trachea			—					111		287
trabecula			154					147		380
end			—					347		896

TABLE 15

Coluber melanurus, SHIELDS

SEX	VENTRALS	SUBCAUDALS	ROWS
♂ Djak	228	88	19–19–17
de Rooy	193–234	89–115	19
Smith	193–234	85–115	19–19–17
♀ Djak	226	86	19–19–17

‰ of the body length, 165 exactly as in the males.

There is little or no asymmetry in the length of the right and left testes, but in males the right kidney is about one-fourth longer than the left one.

INTERVALS: The interval between the pancreas and the left kidney is 234 ‰ of the body length in the male animals, 248 ‰ in the female.

LUNG: In these two young animals there is no difference in the topography of the lung: in the male the apex is at 270 ‰, in the female at 276 ‰; the end of the trabecular part of the lung is at 384 ‰, resp 380 ‰ of the body length. In the female only, the end has been noted rather far to the caudal end of the body (896 ‰).

SHIELDS: In one male and in the female the number of shields is counted: the figures are given in Table 15. There is no difference between the sexes.

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Strontium-90 and Gross Beta Activity in the Fat and Nonfat Fractions of the Liver of the Coconut Crab *(Birgus latro)* Collected at Rongelap Atoll during March 1958

DIPTIMAN CHAKRAVARTI and RONALD EISLER[1]

THERE HAS BEEN a large individual variability in the levels of radioactivity per unit weight of biological samples collected in the vicinity of the Eniwetok Test Site (Applied Fisheries Laboratory, 1949, 1953, 1955*a*, 1955*b*; Held, 1960). This variability may be great enough to mask or obscure differences which might exist between species or with time or locality of collection. In most cases, practical considerations do not permit increasing the number of samples in an attempt to elucidate possible differences. The work reported in this paper points out a source of variability that exists in comparing the radioactivity of various samples of coconut crab liver.

Birgus latro, the coconut crab, is of particular interest since it is edible and is known to concentrate strontium-90. In the course of preparing samples of *B. latro* liver for radioassay, it appeared that the fat content varied considerably from specimen to specimen. A crude determination indicated that the fat contained little or no radioactivity, which was expected because of the low mineral content of fat.

It was therefore decided to determine accurately the fat content and the proportions of strontium-90 and gross beta activity in the fat and nonfat fractions. The objective was to determine whether more uniform results could be obtained when radioisotopic content was expressed on a basis of nonfat solids rather than total solids as had been done in the past.

MATERIALS AND METHODS

Liver samples of the coconut crab were collected from Kabelle, Rongelap, and Eniaetok islands at Rongelap Atoll in March, 1958. The samples were oven-dried at 98 ± 2° C. and partially pulverized. The fat was extracted from the dried samples by a modification of the Johnson method (Winton and Winton, 1945). Petroleum ether was used as the extracting solvent. The fat-free solids were wet-ashed with concentrated HNO_3 and H_2O_2. The ash obtained from nonfat solids was dissolved in a known volume of 1 N HNO_3 and the strontium-90 levels of the samples were determined by the method of Kawabata and Held (1958). The gross beta activity was also measured from an aliquot of the solution. The fat content was determined on a dry weight basis by weighing and on a wet weight basis by using the wet weight to dry weight ratios shown in Table 1. The fat samples were dry-ashed in a muffle furnace at 550° C. overnight. The ash obtained from the fat fraction was dissolved in a small volume of 1 N HNO_3 and was transferred to a plate for determining the gross beta activity. The gross beta activity of the fat fraction was less than 1 per cent of that in the nonfat fraction, making strontium-90 determinations impractical with the facilities available.

All counting was done with an Anton end-window Geiger tube, number 1001-T, which was standardized against a National Bureau of Standards strontium-90 standard.

RESULTS AND DISCUSSION

The ratio of wet to dry weight and the fat content of the liver samples are presented in Table 1. The fat constituted an average of 47 per cent by weight on a wet basis, with a standard deviation of 9.71; and of 74 per cent by weight on a dry weight basis, with a standard deviation of 9.29. The average ratio of wet to dry weight was 1.603, with a standard deviation of 0.156, indicating that the moisture level of the samples was relatively constant.

[1] Laboratory of Radiation Biology (formerly Applied Fisheries Laboratory), University of Washington, Seattle, Washington. Operated under Contract No. AT(45-1)540 with the United States Atomic Energy Commission. Manuscript received September 8, 1959.

TABLE 1

PERCENTAGE OF FAT CONTENT AND THE RATIO OF WET WEIGHT TO DRY WEIGHT OF LIVERS* OF THE COCONUT CRAB *(Birgus latro)* COLLECTED AT RONGELAP ATOLL IN MARCH, 1958

SAMPLE NUMBER	PERCENTAGE OF FAT IN LIVER		WET WEIGHT
	Wet	Dry	DRY WEIGHT
34	44.70	78.81	1.763
35	48.24	74.38	1.542
36	31.50	55.37	1.758
37	38.01	67.88	1.786
38	42.34	67.99	1.606
61	40.38	71.83	1.779
62	42.76	73.04	1.708
84	56.10	83.20	1.483
85	64.62	87.69	1.357
86	50.76	71.02	1.399
87	61.49	88.55	1.440
88	43.89	70.97	1.617
Mean	47.07	74.23	1.603
Standard deviation	9.71	9.29	0.156

* Sample weights ranged from 9 to 18 g.

Strontium-90 levels expressed as disintegrations per minute per gram of nonfat solids and of total solids given on a dry weight and a wet weight basis are presented in Table 2.

Table 3 presents the gross beta activity in the fat and nonfat fractions of the liver. Although fat constituted an average of 47 per cent of the wet weight and 74 per cent of the dry weight (Table 1) of the total solids, gross beta activity of the fat fraction amounted to less than 0.5 per cent of the total sample on a wet weight basis, and less than 1.0 per cent on a dry weight basis.

The gross beta activity of the samples on a wet and dry weight basis is given in Table 4.

There is a linear relationship between strontium-90 activity and gross beta activity (Tables 2, 3). The percentage of gross beta activity due to strontium-90 at Kabelle, Eniaetok, and Rongelap islands, on a nonfat solid dry weight basis, and based upon the average values at each island, is 32, 35, and 31 per cent, respectively.

TABLE 2

STRONTIUM-90 IN NONFAT SOLID AND TOTAL SOLIDS IN LIVERS OF THE COCONUT CRAB *(Birgus latro)*

SAMPLE NUMBER	LOCATION OF COLLECTION	NONFAT SOLIDS d/m/g		TOTAL SOLIDS d/m/g	
		Wet	Dry	Wet	Dry
34	Rongelap Atoll	260 ± 10*	458 ± 17*	55 ± 2*	97 ± 4
35		353 ± 13	544 ± 20	90 ± 3	140 ± 5
36	Kabelle Island	276 ± 12	484 ± 20	130 ± 5	288 ± 10
37		605 ± 35	1080 ± 44	194 ± 8	347 ± 14
38		420 ± 20	674 ± 33	134 ± 6	216 ± 11
Mean		383	648	121	218
Standard deviation		140	255	52	103
84	Rongelap Island	236 ± 10	350 ± 15	40 ± 2	59 ± 3
85		245 ± 11	332 ± 13	30 ± 1	41 ± 2
86		159 ± 8	222 ± 10	46 ± 2	64 ± 3
87		409 ± 23	589 ± 33	47 ± 3	67 ± 4
88		224 ± 13	362 ± 21	65 ± 4	105 ± 6
Mean		255	371	46	67
Standard deviation		93	134	13	23
61	Eniaetok Island	248 ± 9	442 ± 17	70 ± 3	124 ± 5
62		321 ± 20	548 ± 34	87 ± 5	148 ± 9
Mean		285	495	79	136
Standard deviation		52	75	12	17

* Counting error is less than 7 per cent.

TABLE 3

GROSS BETA ACTIVITY OF FAT AND NONFAT FRACTIONS AND PERCENTAGE OF GROSS BETA ACTIVITY IN FAT OF COCONUT CRAB (*Birgus latro*) LIVER

SAMPLE NUMBER	LOCATION OF COLLECTION	FAT d/m/g*	NONFAT d/m/g*		PERCENTAGE OF GROSS BETA ACTIVITY DUE TO FAT	
			Wet weight basis	Dry weight basis	Wet weight basis	Dry weight basis
34	Rongelap Atoll	4	1116	1967	0.29	0.77
35		8	1086	1674	0.67	1.36
36	Kabelle Island	6	618	1086	0.45	0.68
37		14	1929	3446	0.44	0.84
38		2	1219	1958	0.11	0.22
Mean		7	1194	2026	0.39	0.77
84	Rongelap Island	1	753	1117	0.18	0.42
85		0	661	897	0.00	0.00
86		–2	513	718	0.00	0.00
87		1	1169	1684	0.13	0.45
88		1	545	882	0.13	0.26
Mean		0.2	728	1060	0.09	0.23
61	Eniaetok Island	6	824	1466	0.49	0.99
62		6	984	1681	0.45	0.97
Mean		6	904	1573	0.47	0.98

* Counting error is less than 8 per cent.

TABLE 4

GROSS BETA ACTIVITY OF LIVER OF THE COCONUT CRAB (*Birgus latro*)

SAMPLE NUMBER	LOCATION OF COLLECTION	TOTAL SAMPLE d/m/g*	
		Wet weight basis	Dry weight basis
34	Rongelap Atoll	617	431
35		563	428
36	Kabelle Island	423	485
37		1196	1110
38		702	627
Mean		700	616
Standard deviation		295	288
84	Rongelap Island	330	188
85		234	110
86		253	208
87		450	194
88		306	257
Mean		315	191
Standard deviation		85	52
61	Eniaetok Island	492	413
62		564	454
Mean		528	434
Standard deviation		51	29

* Counting error is less than 8 per cent.

The strontium units for the liver of coconut crab of earlier collections from Rongelap have been reported previously (Applied Fisheries Laboratory, 1955*a*, 1955*b*; Dunning, 1957). In order to report the strontium units for the March, 1958, collection, Table 5 has been included.

Since the results of these studies show that the fat content is variable and the fat fraction contains practically no minerals or radioactivity, radiochemical analyses of the liver of coconut crab should be made on the basis of nonfat solids rather than on the entire liver, as has been done in the past.

SUMMARY

The values for strontium-90 and gross beta activity in the fat and nonfat fractions from the livers of 12 coconut crabs (*Birgus latro*) collected at Rongelap Atoll during March, 1958, are presented.

Although fat constituted an average of 47 per cent by weight on a wet weight basis (74 per cent on a dry weight basis), gross beta activity of the fat fraction amounted to less than 0.5 per cent of the total activity on a wet weight basis. Fat content on a wet weight basis had a range of 31 to 65 per cent. There is a linear relationship between strontium-90 activity and gross beta activity. Since the fat content of coconut crab liver is variable and the fat fraction contains practically no radioactivity, it is suggested that the radioactivity (and mineral content) of liver samples be compared on the basis of the nonfat solids.

ACKNOWLEDGMENT

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TABLE 5

STRONTIUM UNITS AND CALCIUM IN LIVER OF THE COCONUT CRAB (*Birgus latro*)

SAMPLE NUMBER	LOCATION OF COLLECTION	Sr^{90} d/m/g WET WEIGHT BASIS	mg. Ca/g WET WEIGHT BASIS	STRONTIUM UNITS*
34	Rongelap Atoll	55	7.25	3448
35		90	10.03	4079
36	Kabelle Island	130	23.93	2469
37		194	15.72	5609
38		134	17.18	3545
Mean		121	14.82	3830
Standard deviation		52	6.51	1152
84	Rongelap Island	40	8.39	2167
85		30	5.40	2525
86		46	12.67	1650
87		47	6.18	3457
88		65	10.99	2688
Mean		46	8.73	2497
Standard deviation		13	3.09	668
61	Eniaetok Island	70	8.00	3977
62		87	7.22	5477
Mean		79	7.61	4727
Standard deviation		12	0.55	1055

* Strontium unit = micro-microcurie of Sr^{90} per gram of calcium.

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ROCK, JOSEPH F. 1916. The sandalwoods of Hawaii; a revison of the Hawaiian species of the genus *Santalum*. J. Aust. Inst. Agric. Sci. 12(3): 1–43, 13 pls.

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VOL. XV APRIL 1961 NO. 2

PACIFIC SCIENCE

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Studies on Spawning Behavior, Egg Masses, and Larval Development in the Gastropod Genus *Conus*, Part I Observations on Nine Species in Hawaii[1]

ALAN J. KOHN[2]

THIS REPORT deals chiefly with the characteristics of egg masses and the course of larval development of gastropod mollusks of the genus *Conus*, based on material collected in the Hawaiian Islands during 1954–56, while the author was at the Hawaii Marine Laboratory. Some information has been obtained on 9 of the 33 species of *Conus* known to occur in the Hawaiian archipelago (Kohn, 1959*a*).

Bergh stated (1895: 100), "Ueber Paarung, Eilegen und Laich der Coniden ist ... absolut nichts bekannt."

The only reference prior to that date which has come to the attention of the present writer is an extremely brief description of the oöthecae or egg capsules of *C. capitaneus* Linnaeus by Adams and Adams (1853: 5). Cooke (1895) and Hornell (1922) figured egg capsules of unidentified species of *Conus*, but Lamy (1928), in an extensive study of prosobranch egg capsules, noted their similarity to those of other genera. These early figures cannot be assigned with certainty to *Conus*, and Bergh's statement remained essentially correct until Petit and Risbec (1929) and Risbec (1931, 1932) described the egg masses and development of four species of *Conus* from New Caledonia. Subsequently, similar information on six additional species has been reported by Thorson (1940), Persian Gulf; Lebour (1945), Bermuda; Knudsen (1950), West Africa; Natarajan (1957), India. More recently Lewis (1960) has provided additional information on the egg capsules and larvae of *C. mus* Hwass *in* Bruguière, a species discussed also by Lebour (1945).

Ostergaard (1950) described the spawning and development of six species of *Conus* in Hawaii. The present paper provides information on five additional species and notes on development in one species mentioned by Ostergaard but not studied in detail by him.

Most of the material was collected on coral reefs which fringe much of the Hawaiian coastline and provide suitable spawning sites for a number of species of *Conus* (Kohn, 1959*b*). Bouin's solution and 10 per cent sea water formalin were used as fixatives. Except where stated otherwise, all material was collected by the author, and the numbers used to identify specimens are those of the author. The preserved egg capsules and embryological material have been deposited in the University Zoological Museum, Copenhagen.

GENERAL CHARACTERISTICS OF SPAWNING AND EGG MASSES

As is typical of the higher prosobranch gastropods, the sexes are separate and fertilization is internal. The prominent penis of the male is a flattened muscular tube which arises from the right side of the dorsolateral body wall just behind the head and is rounded or pointed at the tip (Bergh, 1895: 97, figs. 4, 5, 76, 149, 159).

In copulation, it is inserted into the vagina of the female, which is located anteriorly at the extreme right edge of the mantle cavity, where the mantle joins the body wall, and adjacent to the anus (unpublished observations). A detailed account of the genital apparatus of prosobranchs has been given by Fretter (1941, 1946).

Although the process of oviposition in *Conus* has not been studied closely, it is essentially similar to that first described in other higher prosobranchs (Order Neogastropoda) by Cunningham (1899) and later amplified by Ankel (1929), MacGinitie (1931), and Ino (1950). Eggs surrounded by albuminous, probably nu-

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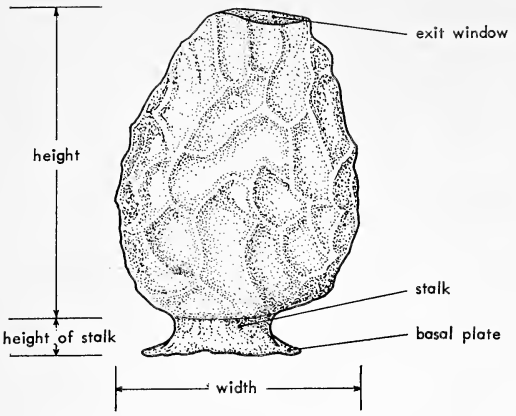


FIG. 1. Generalized egg capsule of *Conus*, with terms used in presentation of dimensions.

tritive, material are passed out of the genital aperture of the female downward through a temporary groove on the side of the foot to the egg capsule gland, which is situated on the anterior portion of the sole. The fluid mass of eggs passes into the aperture of the gland, in which horny egg capsules are produced. This method of egg capsule formation is characteristic of the Neogastropoda, in contrast to the Mesogastropoda in which the capsule is secreted in the genital ducts and only moulded and hardened by the egg capsule gland (Ankel, 1929; Fretter, 1941).

The general shape of the capsules (see Fig. 1) is "like a flattened pouch or flask" (Knudsen, 1950). As will be shown below and in a forthcoming paper (Kohn, MS), there is a moderate degree of interspecific variation in the form of the egg capsules and, in some species, considerable intraspecific variation. It is usually not possible to determine the species to which an egg mass belongs in the absence of the parent. This is in marked contrast to the egg capsules of some other prosobranch genera, e.g., *Murex* and *Nassa*, which are highly species-specific (Thorson, 1959).

The capsule is typically white or straw-colored and is presumably constructed of conchyolin, a scleroprotein. The capsules are deposited in clusters which frequently consist of several short rows of a few capsules each. A cluster of egg capsules is referred to as an egg mass, following Thorson (1940, *et seq.*) and others. The number of capsules deposited in a cluster and the number of eggs per capsule are variable. In the material collected in Hawaii, the number of capsules per cluster ranged from 1 to 68 (Table 1) and the number of eggs per capsule from 80 to about 10,000 (Table 2).

In most species, each capsule is attached to the substratum, usually the underside of a rock, by an adhesive basal plate (Fig. 1). There is a narrow, short stalk, above which is the capsule proper. Its walls are thin, nonrigid, and translucent, and they usually bear ridges on the flat surfaces. The lateral edges are typically convex, and there is a preformed exit window along the straight, uppermost part of the capsule. It is covered by a hyaline membrane or operculum, which is never very thick and appears to become thinner and more transparent as development proceeds. The hatching process has not been studied closely, but it appears that the entire membrane dissolves prior to escape of the larvae. This is in contrast to the family Muricidae, in which the egg capsule is closed by a thick operculum which is lost intact at hatching (Ankel, 1937; Hancock, 1956). Dissolution of the operculum may be due to an enzyme liberated by the larvae just prior to hatching (Ankel, 1937). The larvae of *Conus* do not occupy the entire capsule before hatching.

DEVELOPMENT WITHIN EGG CAPSULE

To study the course of larval development, egg masses were kept in constantly aerated running sea water in finger bowls or wide-mouth 4-l. jars. Following hatching, the larvae were kept in the larger jars in aerated, but not circulating, sea water. In some cases, sand and coral rocks from the normal habitat were placed on the bottom of the vessel in an effort to induce settling of the larvae, but this was generally unsuccessful. Details of embryonic development are described below for those species in which they could be determined, and present knowledge of development in *Conus* is reviewed in the section, Discussion.

Conus abbreviatus Reeve

A cluster of 33 egg capsules was found attached to the underside of a metal refuse can

TABLE 1

COLLECTION RECORDS AND CHARACTERISTICS OF EGG MASSES OF *Conus* IN HAWAII

SPECIES	LOCALITY[1]	DATE OF COLLECTION	SPECIMEN NUMBER	NO. OF CAPSULES IN CLUSTER	HEIGHT × MAXIMUM BREADTH OF CAPSULES (mm.)
abbreviatus	Waikiki	15 III 1923	(Ostergaard, 1950)	12	10 × 8
abbreviatus	Diamond Head	10 III 1956	1382	33	9 × 7–7.5
catus	Waikiki	12 VI 1922	(Ostergaard, 1950)	19	12 × 9
catus	Paia, Maui	5 VIII 1956	2180	1	12 × 10
catus	Koko Head	22 VIII 1956	2299	3[2]	11–12 × 10
catus	Koko Head	22 VIII 1956	——	4	10–11 × 8.5–9.5
ebraeus	Waikiki	22 III 1921	(Ostergaard, 1950)	—	10 × 10
imperialis	Diamond Head	6 VII 1956	1983	6[3]	18–20 × 12–13
leopardus	Kaneohe Bay	25 IV 1956	——	19	49–58 × 34–37
lividus (?)	Maile	7 II 1956	1264	36, 30	10.5–12 × 10–12; 9–10 × 8.5–10
pennaceus[4]	Waikiki	19 V 1921	(Ostergaard, 1950)	34	11 × 8
pennaceus[4]	Waikiki	25 V 1922	(Ostergaard, 1950)	—	——
pennaceus	Waikiki	26 VII 1954	156	20	8.5 × 7.5
pennaceus	Waikiki	4 VIII 1955	——	38	——
pennaceus	Diamond Head	13 VIII 1955	401–404	68, 50, 25, 9	——
pennaceus	Hauula	9 VI 1956	1811	34	9–10.5 × 7–8
pennaceus	Mahie Point	9 VI 1956	1810	58	9.5–11 × 7.5–9
pennaceus	Diamond Head	10 VI 1956	——	68	12–13 × 9–10
pennaceus	Diamond Head	4 VII 1956	1962	10	9–11 × 8
quercinus	Kaneohe Bay	9 II 1956	——	40	19–26 × 17–22
quercinus	Kaneohe Bay	9 II 1956	——	3	17–19 × 18–20
rattus	Waikiki	4 VIII 1921	(Ostergaard, 1950)	22	15 × 11
rattus (?)	Waikiki	21 III 1956	——	31	12–14 × 11–14
vexillum[5]	Waikiki	16 V 1921	(Ostergaard, 1950)	34	20 × 13
vitulinus	Ala Moana	7 VII 1956	2020	11	23 × 16–17
vitulinus	Diamond Head	VII 1957	——	—	——

[1] All from the island of Oahu unless otherwise indicated.
[2] Oviposition possibly interrupted by collector.
[3] Oviposition definitely interrupted by collector.
[4] This species is referred to as *C. omaria* Hwass by Ostergaard (1950).
[5] This species is referred to as *C. sumatrensis* Hwass by Ostergaard (1950).

cover in 1 m. of water on the reef at Diamond Head, Oahu, 10 March 1956. The capsules (Fig. 2) were affixed to their substratum in three rows of 12, 17, and 14. Two adult *C. abbreviatus* (no. 1382, ♀, 29 × 21 mm.; no. 1383, sex undet., 32 × 21 mm.) were found about 1 m. from the can lid, which appeared to be the nearest available protected site for oviposition, since all nearby coral rocks were buried to a depth below the oxidized surface layer of sand. This egg mass is tentatively assigned to *C. abbreviatus* because of the proximity of the adults and the close similarity with the egg capsules of that species described by Ostergaard (1950).

The shape of the capsules is typical of the genus. They are slightly higher than broad and are affixed to the substratum by a short stalk and broad basal plate. The capsular walls are smooth except for peripheral ridges on one side (Fig. 2*b*) and two ridges extending downward from near the upper corners on the opposite side (Fig. 2*c*). Both lateral edges of the capsule are convex. The characteristics of the egg mass are summarized and compared with that studied by Ostergaard (1950) in Tables 1 and 2.

In order to study the course of development, the egg mass was placed in aerated circulating sea water. One egg capsule was removed from the cluster and its contents examined on the day of collection. The embryos, which were pink in color when viewed through the translucent capsular wall, were found to be in the blastula

stage, with the four macromeres and many micromeres distinctly visible. It is likely that the embryos were 1–2 days old. They were oval in shape, measured 175–200 × 165–175 μ, and were slowly motile when released from the capsule into sea water. The blastula is the earliest stage at which activity is observed in *Conus* embryos (Ostergaard, 1950).

An egg capsule opened on the second day after collection contained motile embryos which resembled early trochophores (Fig. 3*a*). The resemblance of this stage to typical trochophore larvae is somewhat closer in *C. abbreviatus* than in other species of *Conus* (see below and Ostergaard, 1950) in which the trochophore stage is suppressed. This is typical of gastropods in which this stage is passed within an egg capsule or brood pouch (Raven, 1958).

The trochophore-like embryos of *C. abbreviatus* measured 270 × 170 μ and retained the pink color of the previous stage. On the fourth day after collection, the first traces of shell were visible (Fig. 3*b*). Two days later, velar lobes were beginning to form (Fig. 3*c*) and the embryos, which now measured 255 × 150–165 μ, swam actively when released from the capsule. On the 9th day after collection the velar lobes and larval shell appeared to be fully developed (Fig. 3*d–f*). The pink color persisted, and the shells were transparent and bore numerous fine nodules (Fig. 3*d, e*). Otocysts, eyes, heart, foot, and operculum were easily visible. The maximum dimension of the shell was 270 μ, and the breadth of the velar lobes was about 250 μ. The veligers were motile within the capsule and swam actively when released from it into sea water. No further development was detected on the 11th day after collection. On the 13th day after collection, presumably the 14th or 15th day after oviposition, some veligers hatched from egg capsules following apparent dissolution of the exit window. The hatched veliger larvae closely resembled those in Figure 3 *d–f* but measured 275–300 μ in maximum shell dimension. They swam freely in the container and were colorless except for a row of green pigment spots inside the margins of the velar lobes (Fig. 3*e, f*). Unhatched veligers within the capsule retained the pink color in the visceral mass.

FIG. 2*a*. Egg capsules of *Conus abbreviatus* Reeve. Diamond Head, Oahu, 10 March 1956. Portion of a row of capsules affixed to metal can lid.

Within two days the rest of the veligers appeared to have hatched from the capsules. During the ensuing 10 days no further development was observed and none of the larvae settled to the bottom of the container to assume the benthic mode of life. By the 11th day after hatching, all of the larvae were dead and the observations were terminated. The course of larval development is summarized and compared with that of other species in Table 3.

Conus catus Hwass *in* Bruguière

A specimen of *C. catus* (no. 2180) collected at Lower Paia, Maui, on 5 August 1956, was observed to have affixed a single egg capsule to its shell about 2 hr. after collection. The capsule measured 12 × 10 mm.

On 22 August 1956, a female *C. catus* (no.

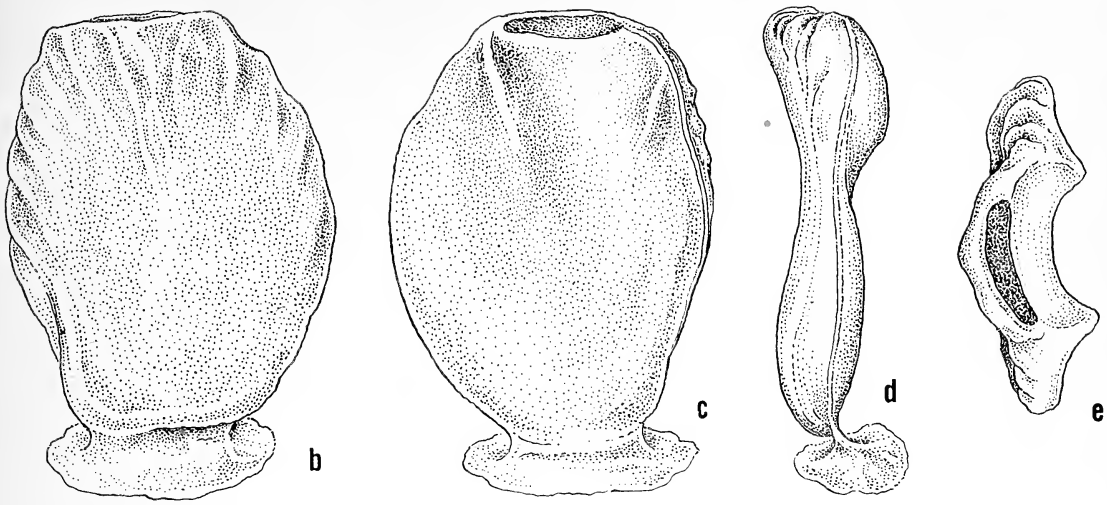


FIG. 2*b–e*. *b,c,d*, Side and edge views of one capsule; *e*, top view of another capsule.

2299, 40 × 26 mm.) was found ovipositing at Koko Head Sandy Beach, Oahu, by M. A. Kohn. Three capsules had been deposited, and spawning probably would have continued had not the adult been disturbed. However, a second cluster of 4 essentially identical capsules, unaccompanied by an adult, was also collected (Table 1). Ostergaard (1950) figured 19 capsules in an egg mass of *C. catus*.

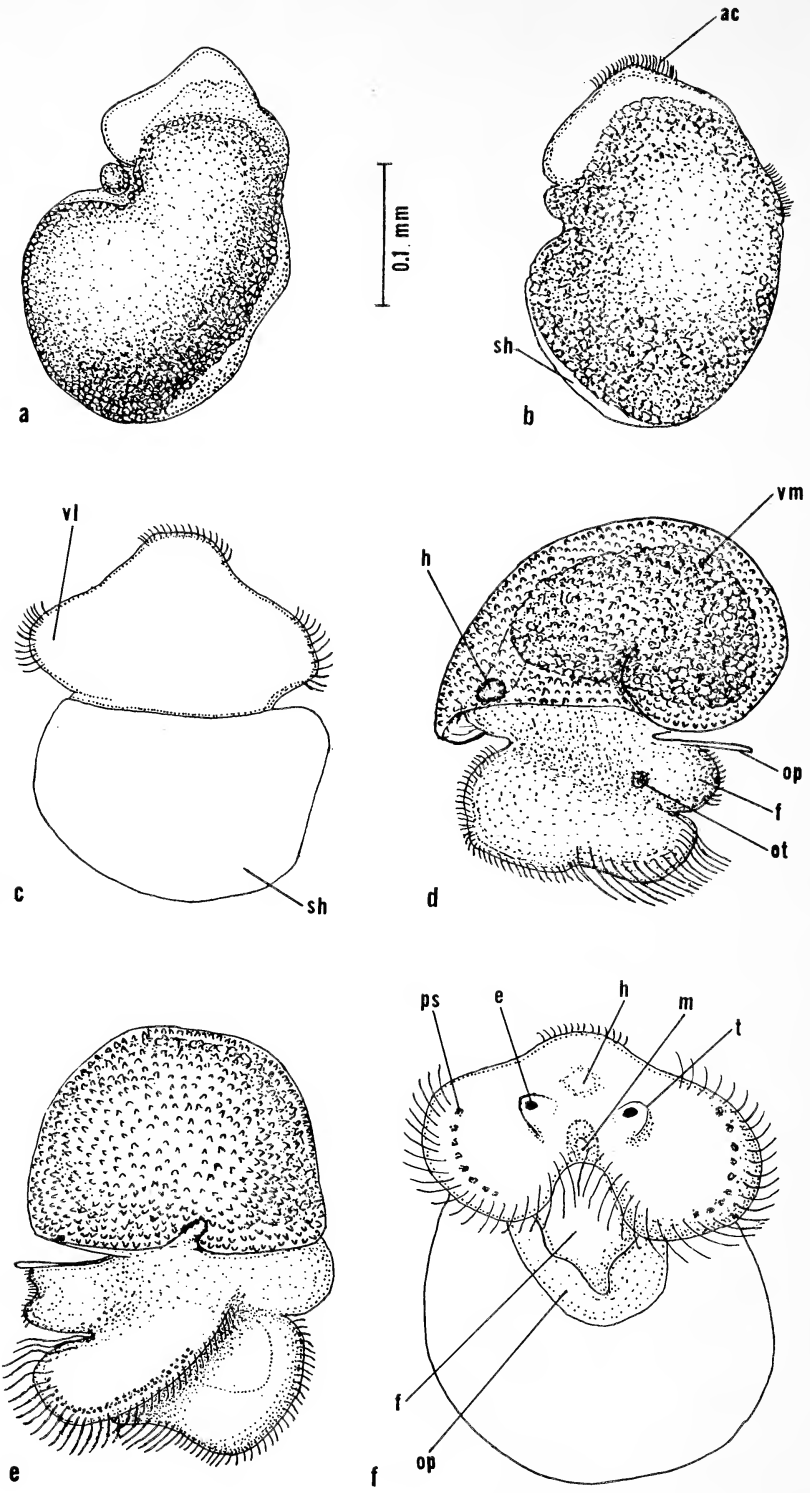
The form of the egg capsules of *Conus catus* is typical, although the stalk is somewhat taller than in other species of the genus (Fig. 4). The lateral edges are slightly convex; the upper edge is quite straight. Capsules in both clusters contained embryos in the 4-cell stage which measured 250–300 μ across. A few uncleaved eggs 235 μ in diameter were present in one capsule. The characteristics of these egg masses are sum-

TABLE 2

NUMBER OF EGGS PRODUCED, EGG DIAMETER, LENGTH OF DEVELOPMENT BEFORE HATCHING, AND STAGE AT HATCHING OF *Conus* IN HAWAII

SPECIES	AVERAGE NO. EGGS/CAPSULE	AVERAGE NO. EGGS/EGG MASS	AVERAGE EGG DIAMETER (μ)	TIME OF DEVELOPMENT IN EGG CAPSULE (days)	STAGE AND SIZE AT HATCHING	
abbreviatus	1,300	44,000	200	14	veliger	270μ
catus	1,650	15,000[1]	220	15–16[1]	veliger	375μ[1]
ebraeus	——	——	——	——	veliger[1]	280μ[1]
imperialis	5,900	(35,400)	225	——	——	——
leopardus	2,950	56,000	——	——	veliger	360μ
lividus (?)	——	——	——	——	veliger	250μ
pennaceus[2]	80	3,500	460	16[1]	veliconcha	1200μ
quercinus	9,700	210,000	215	15–16	veliger	285μ
rattus	2,000[1]	44,000[1]	125[1]	——	(?)veliger	240μ
vexillum[3]	"thousands"[1]	——	140[1]	12[1]	veliger	250μ[1]
vitulinus	——	——	225	14–15	veliger	360μ

[1] Data from Ostergaard (1950).
[2] This species is referred to as *C. omaria* by Ostergaard (1950).
[3] This species is referred to as *C. sumatrensis* by Ostergaard (1950).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marized in Tables 1 and 2. It was not possible to follow the course of larval development, but Ostergaard (1950) has described the development of *C. catus* in some detail.

Conus imperialis Linnaeus

A female *C. imperialis* (no. 1983, 79 × 23 mm.) was observed ovipositing in a depression on the side of a large dead coral head in 0.3 m. of water at Diamond Head, Oahu, on 6 July 1956. Six capsules had been deposited when the rock was turned over and oviposition was interrupted. The capsules are rather long and narrow, measuring about 19 × 13 mm., and do not rise vertically from the stalk and basal plate but are skewed to one side (Fig. 5). Upon return to the laboratory, one of the capsules was pierced and some of its contents withdrawn with a pipette. The eggs were uncleaved and measured 225 μ in diameter. Eggs in the same capsule had not undergone the first cleavage 3.7 hr. later. Twenty-four hr. later, however, eggs in the same capsule had progressed to the 4-cell stage, which measured 250 μ on each side and resembled the 4-cell stage of *C. quercinus* (Fig. 12*c*).

On the 3rd day after oviposition, a second capsule was examined and found to contain embryos in the blastula stage. No further development took place in the cultures and all of the embryos appeared to be dead and were fixed on the 16th day after oviposition. The egg masses and larval development, as far as it could be studied, agree closely in the same species studied in the Seychelles Islands (Kohn, MS). The characteristics of the egg mass from Oahu are summarized in Tables 1 and 2.

Conus leopardus (Röding)

A cluster of 19 very large egg capsules was found adrift in Kaneohe Bay, Oahu, at a depth of 5 m. by A. H. Banner on 25 April 1956. The basal plates of the capsules were confluent, holding the entire mass together. A bright green filamentous alga was associated with the egg

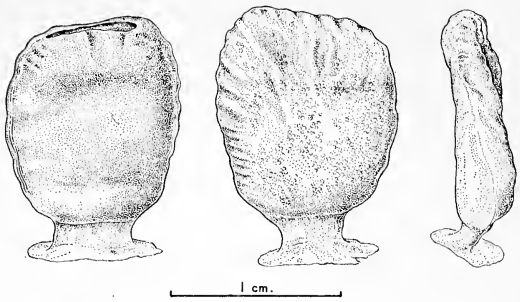

FIG. 4. Views of an egg capsule of *Conus catus* Hwass *in* Bruguière. Koko Head, Oahu, 22 August 1956.

mass when it was collected. However, the original substratum from which the mass presumably became detached is not known. The largest capsule measured 58 × 37 mm., exclusive of stalk and basal plate, and the average size was 54 × 35 mm. This is about twice as large as any other known *Conus* egg capsule. For this reason the egg mass is tentatively assigned to *C. leopardus*, which is by far the largest species in the family in Hawaii, reaching a length in excess of 20 cm. The capsules were collected in an area where *C. leopardus* is known to occur.

The capsules differ in shape from those of other species of *Conus* by having one lateral edge concave (Fig. 6). The capsular wall is roughened by numerous irregular ridges.

It was not possible to examine the contents of the egg capsules until 2 days after collection. At that time typical veliger larvae, measuring 345 μ in maximum shell dimension, were present. Thus although the adults and egg capsules of *C. leopardus* are very large, the veliger larvae, and presumably the eggs, are not significantly larger than those of much smaller species (Table 2). Indeed the veligers are much smaller than those of *C. pennaceus* (Table 3), the adults of which species are typically one-fourth or less the size of *C. leopardus*.

FIG. 3. Developmental stages of *Conus abbreviatus* Reeve. *a*, 3- or 4-day embryo, in modified trochophore stage; *b*, 5- or 6-day embryo, with first trace of shell present; *c*, 7- or 8-day embryo, showing developing velar lobes; *d*, fully-formed veliger, 10 or 11 days, lateral view; *e*, as *d*, but anterior-lateral view; *f*, as *d*, but anterior-ventral view, showing expanded velar lobes and ventral aspect of foot and operculum. *ac*, Apical cilia; *e*, eye; *f*, foot; *h*, heart; *m*, mouth; *op*, operculum; *ot*, otocyst; *ps*, pigment spot; *sh*, shell; *t*, tentacle; *vl*, velar lobe; *vm*, visceral mass.

TABLE 3

COURSE OF EMBRYONIC DEVELOPMENT IN HAWAIIAN *Conus*

DAYS AFTER SPAWNING[1]	*C. abbreviatus*	*C. pennaceus*	*C. quercinus*	*C. vitulinus*
0–1	blastula (200μ)[2]	early cleavage stages (460μ)	uncleaved eggs (200μ)	early cleavage stages (225μ)
2–3	early trochophore (270μ)		early blastula	blastula (225μ)
4–5	well-developed trochophore (240μ)	late trochophore	blastula (200μ)	
6–7	early veliger (255μ)		trochophore (240μ)	trochophore (360μ)
8–9			early veliger (315μ)	veliger (385μ)
10–11	well-developed veliger (270μ)	well-developed veliger (780μ)	well-developed veliger (275μ)	
12–13			well-developed veliger (285μ)	
14–15	hatching (veliger) (300μ)		hatching (veliger) (290μ)	hatching (veliger) (370μ)
16		hatching[3] (veliconcha) (1200μ)		
17–25	no further development			

[1] Probable in *C. abbreviatus*.
[2] Maximum dimensions are indicated in parentheses.
[3] Data from Ostergaard (1950).

Only 2,950 veligers were present in the one capsule which was counted, and they occupied but a small portion of the capsule. As in several other species, yellowish-green pigment spots about 10 μ in diameter were present inside the margins of the velar lobes. A large operculum, a pair of otocysts, each containing an otolith, and black eyes were present. The long (*ca.* 75 μ) velar cilia beat slowly and metachronally. The larval shell was transparent but covered with minute (*ca.* 2 μ) raised dark nodules. The visceral mass appeared white within the shell.

Several hours later on the same day, hatching began and the hatched veligers, which measured 360 μ in maximum shell dimension, swam about slowly in a 4-l. jar of aerated sea water. On the following day, the jar was densely populated with freely swimming veligers, which swam more rapidly than on the previous day. The population was then divided between two 4-l. jars. Three days later, most of the veligers had died. Four of those which remained alive were placed in a large Stender dish (*ca.* 120 mm. in diameter) containing sea water and sand from the reef. Of these, three continued to swim about, but one settled to the bottom, where it actively beat its cilia and possibly engaged in feeding. If disturbed, it swam actively for a few seconds, then returned to the bottom. However, it was not observed to crawl on its foot, nor was there any evidence of resorption of the velar lobes or other manifestation of metamorphosis. On the following day, all four larvae in the dish were dead. Two days later, the 6th day after hatching, a few swimming veligers remained in one jar, but the observations had to be terminated.

Conus lividus Hwass *in* Bruguière (?)

On 7 February 1956, at Maile, Oahu, two clusters of straw-colored egg capsules were found affixed to the underside of a coral rock, under which a large female *C. lividus* (no. 1264, 45 × 26 mm.) was also present. One cluster consisted of 36 egg capsules, all of which were empty, and the other contained 30 capsules, some of which contained dead veliger larvae. Since these capsules were probably deposited

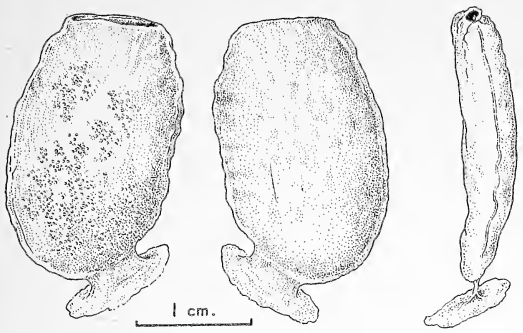

FIG. 5. Views of an egg capsule of *Conus imperialis* Linnaeus. Diamond Head, Oahu, 6 July 1956.

two or more weeks prior to their collection, it is by no means certain that the adult female associated with them was the parent. Indeed, it is not certain that the capsules are actually those of *C. lividus*, and the identification is tentative. It is supported, however, by morphological similarities with capsules known to have been deposited by *C. lividus* in other areas (Kohn, MS).

The capsules are distinguished from those of several other species of *Conus* by being somewhat more discoid in form and bearing crenations along the edges of the otherwise rather smooth capsular wall (Fig. 7). There are also two more or less parallel ridges extending downward from the corners of the exit window, as in *C. abbreviatus*. The capsules in the smaller group, shown in Figure 7, averaged 11 mm. in height and maximum breadth. The capsules in the other group were essentially similar in appearance but were slightly smaller, averaging 9.5 mm. in both dimensions.

The veliger shells, 235–260 μ in maximum dimension, were yellowish brown and bore minute densely-packed, raised, darker brown nodules over the entire surface.

Conus pennaceus Born

Egg masses of *C. pennaceus* have been collected on numerous occasions in Hawaii (Table 1). As noted by Ostergaard (1950) the egg mass of *C. pennaceus*[3] differs from those of other species in that only a few capsules are attached directly to the substratum. Most are affixed to previously deposited capsules, thus forming the "arches and bridges" mentioned by Ostergaard and making the entire mass very compact (Fig. 8). The individual capsules are typical of the genus (Fig. 9).

In the present study, 10 egg masses of *C. pennaceus* were collected on seven occasions, all in the months of June, July, and August (Table 1). The 2 egg masses reported by Ostergaard (1950)[3] were collected in May. The data suggest May–August as the breeding season of this species.

The development of *C. pennaceus* from fertilized egg to hatching has been described and illustrated by Ostergaard (1950). It was possible to follow portions of the course of larval development in 2 of the egg masses listed in Table 1.

On the day after collection, the egg mass from Diamond Head, Oahu, 10 June 1956 (which was found adrift over the reef by P. Helfrich), contained early veliger larvae which appeared to be in the later stages of torsion. A very small shell rudiment, a slowly beating heart, and eyes were present. On the 4th day after collection, the veligers appeared to be between the stages shown by Ostergaard's figures 11d and 11e, or probably about 12–13 days from oviposition. The siphonal canal of the shell had begun to form, and a row of chartreuse pigment spots was present along the margin of the velar lobes.

During the next 7 days, the shells gradually grew to 1.1 $\times$ 0.7 mm., and the wall of the exit window became thinner and more transparent, but no capsules hatched. Hatching of a few capsules finally occurred on the 16th day after collection. This probably corresponded to 25–26

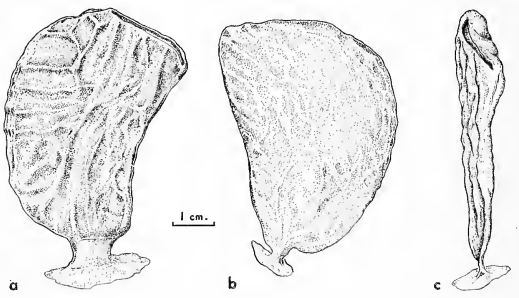

FIG. 6. Egg capsules of *Conus leopardus* (Röding). Kaneohe Bay, Oahu, 25 April 1956. *a*, Side view of one capsule; *b* and *c*, opposite side and edge views of another capsule.

[3] This species is referred to as *C. omaria* Hwass by Ostergaard (1950).

days after oviposition, an abnormally long embryonic period compared with other species and with Ostergaard's observations on *C. pennaceus*. Most of the capsules in the cluster underwent no further change and the observations were terminated.

The egg mass collected at Hauula, Oahu (Table 1) (with an adult female, no. 1811, 35 × 21 mm.) was attached to the underside of a basalt rock in less than 0.5 m. of water. On the day of collection, one capsule was removed from the cluster and found to contain larvae in the advanced veliger or veliconcha stage. The latter term was introduced (Lamy, 1933; Werner, 1939) for fully developed veligers immediately

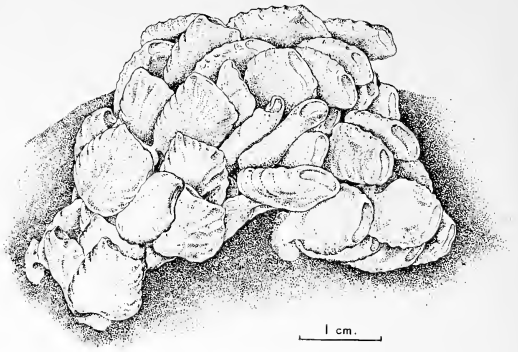

FIG. 8. Egg mass of *Conus pennaceus* Born. Diamond Head, Oahu, 10 June 1956.

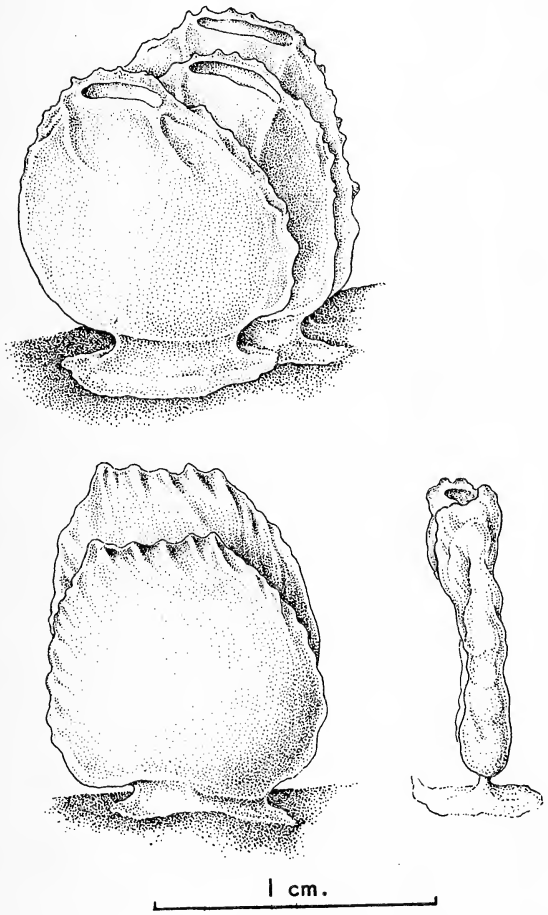

FIG. 7. Views of egg capsules tentatively assigned to *Conus lividus* Hwass *in* Bruguière. Maile, Oahu, 7 February 1956.

prior to metamorphosis. The larval shells were pale orange pink and measured 1.2–1.3 × 0.7 mm. When released from the capsule, the larvae swam with the velar lobes up, a position apparently determined by the weight of the shell. The larvae closely resembled that illustrated by Ostergaard (1950: fig. 11e). The remaining intact capsules were placed in a vessel of slowly circulating aerated sea water and a substratum of sand from the reef.

On the following day, one larva hatched from an egg capsule and, in contrast with those observed by Ostergaard, was quite able to swim about in the dish. However, its velar lobes and shell aperture always pointed upward, and the shell often rested on the substratum. The foot was not employed in locomotion. On the next day, 10 similar free-swimming veliconchas were observed in the dish. Two days later, although larvae remained in some capsules, many had hatched. A sample of these was observed to be distributed in the container as follows:

Freely swimming	0
Resting on bottom with velar lobes extended	
Velar lobes apparently regressing	3
Settled: crawling on substratum	38
Dead: empty shells	1
Sample size	79

The later stages of larval development in *C. pennaceus* may be summarized as follows: the larvae hatch as veliconchas which may swim

freely for about 1 day. They then rest on the bottom with the velar lobes extended upward and the cilia beating. Ostergaard's observation of propulsion along the substratum by the velar cilia was confirmed. Then the velar lobes begin to be resorbed. This was observed in three larvae, in which the margins of the velum were wrinkled and the length and width of the lobes was about one-half of the earlier dimensions. These veliconchas appeared otherwise normal. On the 2nd day after hatching, the young snail begins to crawl about on its foot (Fig. 10). However, the velar lobes have not been completely resorbed by this time; they are often extended by the crawling snail. When the larva assumes the benthic mode of life, the shell becomes darker orange in color, probably due to thickening, and new shell growth is apparent along the outer lip.

Ten days after the first hatching, the shells of the largest individuals measured 1.38 × 0.80 mm. and consisted of two complete whorls. However, mortality gradually increased in the culture, no individuals advanced beyond the end of the second whorl, and on the 27th day after the first hatching only one individual remained alive and the observations were terminated. Post-larval growth of *C. pennaceus* has been discussed elsewhere (Kohn, 1959*b*).

Conus quercinus Solander

Two clusters of egg capsules of *Conus quercinus* were collected in 1–2 m. of water at Sand (Ahuolaka) Island in Kaneohe Bay, Oahu, on 9 February 1956. The larger cluster contained 40 capsules and was affixed to a large clump of the red alga, *Acanthophora orientalis* J. Agardh.

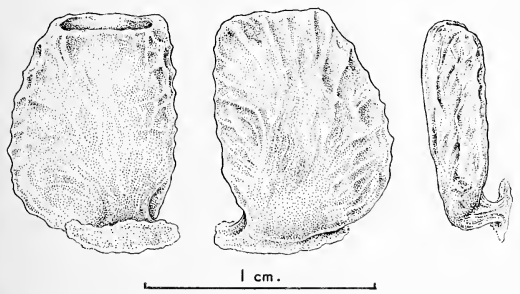

FIG. 9. Views of an egg capsule of *Conus pennaceus* Born. Diamond Head, Oahu, 10 June 1956.

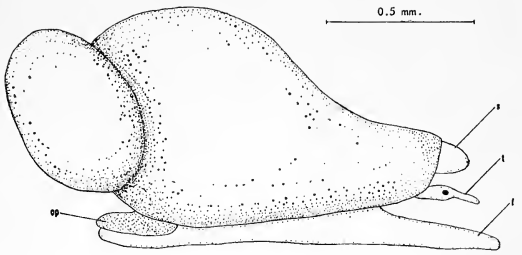

FIG. 10. Settled veliconcha of *Conus pennaceus* Born. *f*, Foot; *op*, operculum; *s*, siphon; *t*, tentacle, bearing the eye.

A pair of adult *Conus quercinus* (no. 1284, ♀, 91 × 56 mm.; no. 1285, ♂) were adjacent to the egg mass, and another pair and three single individuals were present within a radius of 1 m. *C. quercinus* appears to migrate from deeper water and to congregate for spawning in February–April of each year (Kohn, 1959*b*: 81). At this season adults are commonly found in the shallow water around Sand Island, a sand bank which is partially exposed at low tide. At other seasons they are absent from this site (Kohn, 1959*b*: fig. 29). The microhabitat of *C. quercinus* is quite distinct from those of its congeners in Hawaii (Kohn, 1959*b*). It occurs on vast sandy areas generally devoid of coral and rocks. As noted above, the egg capsules in the large mass were anchored to an alga. The other egg mass, which consisted of only three capsules, was affixed to a red sponge.

The congregation of several or many individuals associated with spawning was not observed in any other Hawaiian species of *Conus* but has been observed in other areas and will be discussed more fully elsewhere (Kohn, MS).

Most of the capsules in the large cluster were arranged in rows of up to eight and were affixed to each other by confluence of the basal plates (Fig. 11) as well as to the alga. A few were attached to previously deposited capsules, but this was not as common as in *C. pennaceus* and no bridges were present. The form of the capsules is rather irregular (Fig. 11). One wall bears numerous small ridges; the other has two more distinct ridges proceeding downward from near the corners of the exit window. The capsule is white when deposited but, since the

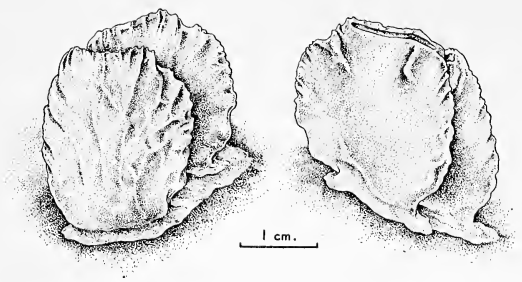

FIG. 11. Portion of a row of egg capsules of *Conus quercinus* Solander. Sand Island, Kaneohe Bay, Oahu, 9 February 1956.

cluster extends upward into the water and is not covered, it soon becomes a substratum for epiflora and epifauna. The characteristics of the egg masses of *C. quercinus* are summarized in Tables 1 and 2.

On the day of collection, one capsule was removed from the large cluster and found to contain pale pink, uncleaved, round-to-ovate eggs embedded in albuminous material and measuring 175–250 μ (Fig. 12*a*). The egg mass had probably been deposited on the same day. On the following day the first cleavage furrow was visible (Fig. 12*b*). On the 3rd day after collection, it was difficult to discern cell outlines, but the embryos, which were now white, appeared to be in the second to fourth divisions (Fig. 12*c, d*) and were motile when released from the capsule into sea water. Another capsule examined on the 5th day after collection showed little further progress. The embryos were quite motile and micromeres were observed in a few. Two days later, the embryos had increased in size to 240 $\times$ 180 μ and were in the modified trochophore stage (Fig. 12*e*).

Two days later, on the 9th day after oviposition, the embryos had grown to a maximum size of 315 $\times$ 195 μ and the shell and velar lobes had begun to form (Fig. 12*f*). Two days later, the fully developed veliger shells had attained a length of 255–295 μ. The velar lobes were well developed, and the heart, kidney (which was bright red), otocysts, eyes, and mouth (which measured 6 $\times$ 23 μ) were visible (Fig. 12*g, h, i*). The small foot rudiment bore a large operculum. The shell was brown and decorated with many rows of brown nodules, which were about 3 μ in diameter, rose 3–4 μ above the surface of the shell, and were about 3 μ apart. The growing lip of the shell was transparent.

On the 13th day after oviposition, the veligers were motile within the capsules and in many they were crowded in the vicinity of the exit window. Veligers removed from one capsule were found to have a row of green pigment spots, about 15 μ in diameter, inside the margins of the velar lobes, which had grown to about 285 μ across. The shells had not increased in size, but the outer lip was no longer transparent, indicating increased thickness. Two days later, on the 15th day after oviposition, some veligers hatched from the capsules and were swimming actively about in the container. By the following day most, and on the next day all, of the capsules had hatched.

Although the foot increased in size during the next few days, no significant over-all growth was apparent, and the velar lobes of some hatched veligers appeared reduced in size (Fig. 12*j*). None of the larvae settled to crawl on the bottom. Mortality in the culture gradually increased and only one or two larvae remained alive on the 8th day after the first hatching, when the observations were terminated.

Conus rattus Hwass *in* Bruguière (?)

A cluster of 31 egg capsules was collected from depressions in the underside of a large coral rock in 1 m. of water on the reef opposite the marine laboratory at Waikiki, Oahu, on 21 March 1956. No adult *Conus* was present in the immediate vicinity, but the capsules closely resemble those of *C. rattus* described by Ostergaard (1950).[4] They are tentatively assigned to that species, which is not uncommon on the same reef.

The capsules (Fig. 13) measured 11–15 $\times$ 10–14 mm. and most were empty. However, a few contained veliger larvae, which hatched soon after being placed in a vessel of sea water in the laboratory. The veliger shells were yellowish brown with darker brown granulations and measured 240 μ in maximum dimension. Eyes and otocysts were visible and a row of green pigment spots was present around the margins of the velar lobe. A few of the larvae remained

[4] This species is referred to as *C. tahitensis rattus* Hwass by Ostergaard (1950).

alive for 13 days after hatching, but they grew only to a length of 250 μ and no further development occurred.

Conus vitulinus Hwass *in* Bruguière

On 7 July 1956, at the reef at Ala Moana, Oahu, an adult *C. vitulinus* (no. 2020, 67 × 38 mm., sex undet.) was collected on sand under a dead coral rock, to the underside of which was attached an irregular cluster of 11 egg capsules. Some of the capsules were attached to others by confluence of the basal plates, but all were affixed to the substratum as well. They measured 23 × 16–17 mm. and their shape was typical of the genus (Fig. 14).

Eight hr. after collection, one capsule was examined and found to contain 1-, 2-, and 4-cell stages, which measured 225 μ in diameter

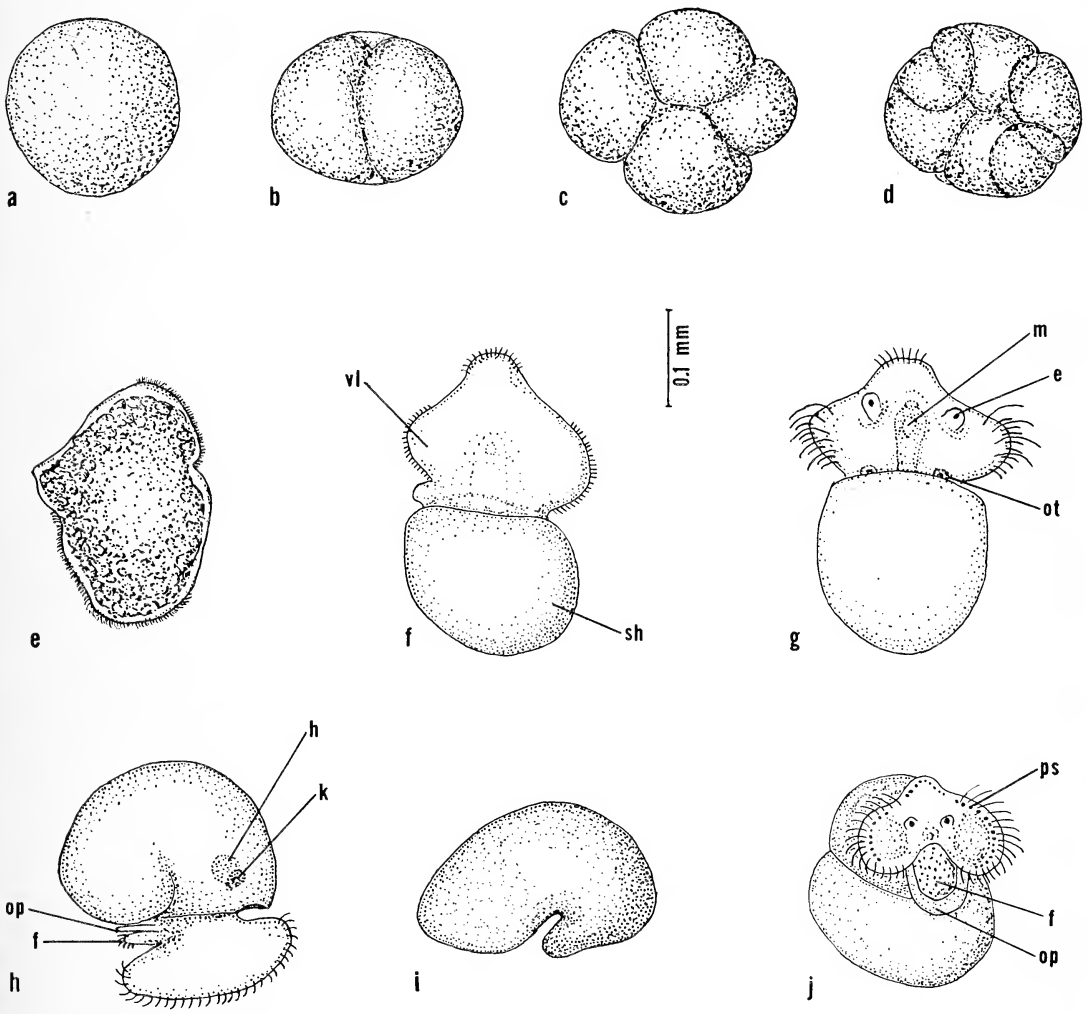

FIG. 12. Developmental stages of *Conus quercinus* Solander, from the same egg mass as the capsules illustrated in Figure 11. *a*, Uncleaved egg; *b*, 2-cell stage; *c*, 4-cell stage; *d*, embryo in third cleavage division; *e*, trochophore-like stage; *f*, early veliger; *g*, developing veliger, anterior-ventral view; *h*, developing veliger, right lateral view; *i*, shell of veliger, left lateral view; *j*, hatched, fully developed veliger. *e*, Eye; *f*, foot; *h*, heart; *k*, kidney; *m*, mouth; *op*, operculum; *ot*, otocyst; *ps*, pigment spots; *sh*, shell; *vl*, velar lobe. Nodules present on shells are not indicated in figures.

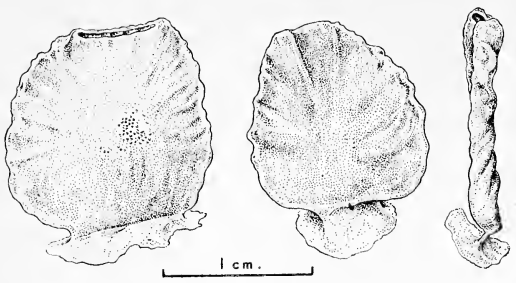

FIG. 13. Views of an egg capsule tentatively assigned to *Conus rattus* Hwass *in* Bruguière. Waikiki, Oahu, 21 March 1956.

(Fig. 15*a*, *b*). Oviposition probably occurred earlier the same day. Two days later, the embryos had progressed to the early blastula stage and macromeres and micromeres were distinctly visible (Fig. 15*c*). A capsule examined on the 6th day after collection was found to contain motile trochophore-like larvae which measured 360 × 210 μ (Fig. 15*d*). On the 9th day, the veliger stage was fully developed, the maximum dimension being 375–400 μ (Fig. 15*e*, *f*). On the 11th day, the veligers were motile within the capsules and on the following day crowding toward the exit window was observed. All of the capsules hatched during the next 3 days, or 14–16 days after oviposition. The otocysts and reddish-brown kidney were visible and green pigment spots almost filled the velar lobes of some individuals.

Some of the veligers swam about freely in the vessel, but most remained on the bottom, which had been covered with sand from the reef, and propelled themselves by beating the velar cilia. When disturbed, they swam briefly away from the source of irritation. However, none of the larvae settled to crawl on their feet, and all had died without undergoing any further growth or development by the 4th day after hatching began.

On 24 July 1957, a cluster of 12 egg capsules was found attached to the underside of a coral rock in a large tide pool at Diamond Head, Oahu. A large adult *C. vitulinus* (no. 7034, 65 × 37 mm., sex undet.) was present on the sand substratum under the rock. Upon return to the laboratory, one of the capsules was examined and found to contain eggs in 1-, 2-, and 4-cell stages; the last measured about 250 μ across. On the second day after collection, a capsule contained embryos which still measured 250 μ in diameter but had progressed to the blastula stage. The observations had to be terminated at this point, but development thus far was essentially similar to that in the egg mass described above.

DISCUSSION

Spawning site and season. Egg capsules of *Conus* have been collected on 31 known occasions in Hawaii, chiefly by Ostergaard (1950) and by the writer and colleagues. All collection records are summarized in Table 1. At least 12 species are represented.

As noted previously (Kohn, 1959*b*):

> Coral reef platforms, but not marine benches, provide suitable attachment sites for egg capsules of *Conus*. Of 36 egg masses collected in the field, 29 were recorded from reef platforms. An almost complete absence of records from marine benches suggests that spawning is unsuccessful there. This is probably due to the absence of protected pools in which egg capsules may be deposited without being subject to desiccation at low tide and/or torn away by heavy surf at high tide. Recruitment of bench populations [of adults] is probably from pelagic veliger larvae which have been carried from other areas and are washed onto marine benches in condition to settle and assume the benthic mode of life.

All of the capsules were collected between February and August, although search for them was not restricted to, or emphasized during, that period. The data suggest that most species of

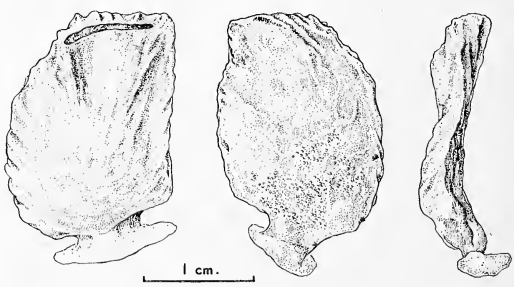

FIG. 14. Views of an egg capsule of *Conus vitulinus* Hwass in Bruguière. Ala Moana, Oahu, 7 July 1956.

Conus spawn during about the same part of the year. The spawning season of most species for which more than one egg mass has been collected is rather extended over the months cited. Capsules containing viable eggs and embryos of *C. rattus* have been collected from February to August, of *C. abbreviatus* from March to July, and of *C. pennaceus* from May to August.

The spawn of most species has been observed only rarely. However, 12 egg masses of *Conus pennaceus* were collected on nine occasions, all in the months of May, June, July, and August, suggesting that these months constitute the breeding season in this species. The preponderance of data for *C. pennaceus* (Table 1) is attributed partly to the fact that the egg masses of this species are readily identifiable, even in the absence of the parent from the collection site. Unlike other species, which attach each capsule to the substratum, *C. pennaceus* attaches only a few to the substratum, while the rest are attached to previously deposited capsules.

Development. The eggs of *Conus* are typically white or pink, spherical or nearly so, and without a surrounding membrane. Polar bodies were not observed, but Ostergaard (1950) reported their occurrence in *C. vexillum*.[5] There are no nurse eggs; all or almost all eggs may develop to hatching in nature, but development was often arrested in a usually small but variable proportion of embryos in egg masses cultured in the laboratory.

The number of eggs produced, egg diameter, length of development before hatching, and stage at hatching are summarized for 11 species of *Conus* from Hawaii in Table 2. Egg diameter was measured in 8 species, of which 7 ranged from 125 μ to 225 μ. In all of these species, the number of eggs was large, about 1,000–10,000 per egg capsule and 15,000–210,000 per egg mass (Table 2). One species, *C. pennaceus,* has much larger eggs (460 μ), of which considerably fewer are deposited (80/egg capsule; 3,500/egg mass).

As can be seen in Table 2, all the species with large numbers of small eggs hatch as free-swimming veligers, while *C. pennaceus* has virtually no pelagic stage, as was discussed in detail above. These data are in agreement with the correlations of large numbers of small eggs with long pelagic life and small numbers of large eggs with nonpelagic development first demonstrated by Thorson (1950, 1952) for mollusks and other benthic marine invertebrates.

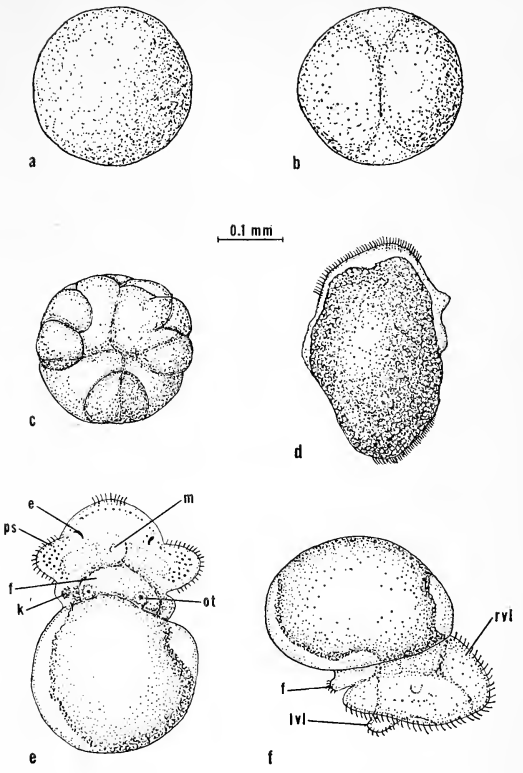

FIG. 15. Developmental stages of *Conus vitulinus* Hwass *in* Bruguière, from the same egg mass as the capsule illustrated in Figure 14. *a,* Uncleaved egg; *b,* 2-cell stage; *c,* early blastula; *d,* trochophore-like stage; *e,* veliger, anterior-ventral view; *f,* veliger, lateral view. *e,* Eye; *f,* foot; *k,* kidney; *lvl,* left velar lobe; *m,* mouth; *ot,* otocyst; *ps,* pigment spot; *rvl,* right velar lobe.

Salient features of development in four species of *Conus* are summarized in Table 3. The eggs are fertilized but have not yet undergone first cleavage when enclosed in the egg capsules. In the species studied, the trochophore stage is entered at 2–6 days, and the veliger stage at 6–10 days, after spawning. Larvae hatch as veligers about 2 weeks after spawning. These observations are in agreement with those of Ostergaard (1950), who also reported on development in

[5] This species is referred to as *C. sumatrensis* Hwass by Ostergaard (1950).

four other species, which hatched 12–16 days after spawning.

In laboratory cultures, many of the veligers (up to 75 per cent) did not succeed in escaping from the capsules. However, this may have been due to the abnormal spatial position of the detached capsules; it is less likely to occur in nature. It has been noted above that the capsules are usually affixed to the underside of a rock. Since the exit window is thus oriented downward in nature, escape of the larvae from the capsule may be facilitated by gravity after disappearance of the membrane covering the exit window. However, in laboratory cultures in which capsules were oriented as shown in Figure 1, larvae ready to hatch were often observed crowded toward the exit window before dissolution of the membrane, and many escaped from the capsule by actively swimming upward. These observations suggest that positive or negative geotropism is not a factor in the hatching of *Conus* larvae.

The length of the pelagic stage could not be determined except for *C. pennaceus*, in which it is only 1 day or less. The maximum survival time of free-swimming veligers in the writer's laboratory was 13 days (*C. rattus*). Partial metamorphosis was observed only in *C. pennaceus*.

The nature of the food of the larval stages is unknown. Protozoa abounded in the cultures. Thorson (1946) concluded that all prosobranch larvae known from the Øresund feed on phytoplankton, and he calculated the theoretical maximum diameter of the food to be 5–45 μ. The mouths of *Conus* veligers measured were of about the same diameter as the esophagus of the smaller larvae measured by Thorson. Thus the larvae of *Conus* probably depend for food on phytoplankton, nannoplankton, and detritus. Examination of squash preparations of *C. pennaceus* a few days after settling revealed the presence of radula teeth. These differ in form from the adult teeth, being shorter in proportion to the thickness, and they are probably not functional. The method of feeding, as well as the food, is thus not known at this stage of the life history. The rather fragmentary information available on post-larval development and growth of *Conus* in Hawaii has been reported elsewhere (Kohn, 1959*b*).

SUMMARY

Egg capsules of 9 of the 33 species of *Conus* found in Hawaii are described and figured. Interspecific variation is usually not sufficient to permit identification of the species to which an egg mass belongs in the absence of the parent.

The complete course of larval development within the egg capsule from spawning (uncleaved egg) to hatching (veliger or veliconcha) is described for 4 species. Early cleavage stages occur 1–3 days after spawning, suppressed trochophore stage at 2–6 days, and veliger stage at 6–10 days. Freely swimming veligers hatched from egg capsules of 3 species 14–15 days after oviposition, in agreement with the developmental time scale of other species of *Conus* previously reported on by Ostergaard (1950).

All species found to have pelagic larval stages produced large numbers (15,000–210,000) of small (125–225 μ) eggs. It was not possible to determine the length of the free-swimming stage in any of these species.

Hatching in one species, *C. pennaceus*, occurs 16–26 days after oviposition at the advanced veliger or veliconcha stage. The larvae swim about for 1 day or less and then assume the benthic habit and begin metamorphosis. This species produces small numbers (3,500) of large (460 μ) eggs. This characteristic is correlated with the absence of a long pelagic larval stage.

ACKNOWLEDGMENTS

This study was aided by a grant from the Sigma Xi–RESA Research Fund, 1959. It was carried out at the Hawaii Marine Laboratory of the University of Hawaii and the Marine Biological Laboratory of the University of Copenhagen. The writer is extremely grateful to Prof. Gunnar Thorson for providing laboratory facilities at the latter institution, access to unpublished data, and stimulating discussions, and for arranging for the services of Mr. P. H. Winther, who drew Figures 2, 4–9, 11, 13, and 14. The other figures were prepared by the author from sketches of living specimens and from camera lucida drawings of fixed material. Appreciation is also expressed to the staffs of the two laboratories mentioned above for much helpful assistance.

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Revision of the Genus *Pandanus* Stickman, Part 2
Pandanus in Western Australia and Notes on the Section Foullioya

HAROLD ST. JOHN[1]

THIS IS THE SECOND PART of a revision of the genus *Pandanus*. The previous one was printed in *Pacific Science* 14(3): 224–241, 1960.

There have been earlier printed reports of *Pandanus* occurring in the state of Western Australia. These all identified the species as ones native to distant areas. The existing specimens from the region are meager, but by examining them in all of the principal Australian herbaria, it has been possible to learn enough of their structure to classify two of them. There are indications of a third species, but the two following are sufficiently known. As they appear to be novelties, they are here described as new species.

Pandanus kimberleyanus sp. nov. (sect. *Microstigma*)
Fig. 9

DIAGNOSIS HOLOTYPI: Arbor? "12–25 ped. alt.," gracilis cum radicibus aereis; *foliis* 1.29 m. longis 6.2 cm. latis prope basi sed 3–7 cm. latis prope medio longe acuminatis circa 10 cm. ex apice 6 mm. latis firmis valde fibrosis marginibus in basi inermibus sed in tertia infera armatis dentibus 2–3 mm. longis subulatis brunneo-cacumenatis adscendentibus 2–13 mm. distantibus sed in tertia medialis in uno latere inermibus et in altero latere cum dentibus simulantibus 9–17 mm. distantibus sed in parte apicali dentibus adscendentibus 0.2–0.5 mm. longis 3–7 mm. distantibus, nervo medio inermi, *inflorescentia* foeminea solitaria et terminali (?), pedunculo 19 cm. longo 7–12 mm. diametro trigono, bracteis numerosis foliosis ad 95 cm. longis 10–14 mm. latis longe acuminatis et subulatis, syncarpio 10 cm. longo 7.5 cm. diametro ovoideo obtuse subtrigono, *drupis* 2.5–2.8 cm. longis 1.2–1.3 cm. latis 1 cm. diametro in basi 5–10 mm. latis, corpore anguste obovoideo coloribus incognitis in sicco epidermatibus exfoliatis fibris longitudinalibus numerosis nudatis, caverna apicali parte cum tubera brunnea cumpleta, stigmate 2 mm. lata anguste lunata excentrale in margine sentinae apicale, endocarpio minime submediale osseoso obscure brunneo muris externis 1.5 mm. crassis, seminibus 7 × 5.5 mm., mesocarpio apicalis caverno singulo, mesocarpio basilari carnoso et valide fibroso.

DESCRIPTION OF ALL SPECIMENS EXAMINED: Tree, "erect, 12–25 ft. high," slender and with prop roots; *leaves* 1.27–1.29 m. long, 6.2 cm. wide near the base, 3.7–6.1 cm. wide near the middle, long tapering to a slender, narrowing tip, the actual tip (probably about 3 cm. long and 2 mm. wide) is missing, and at about 10 cm. from the tip it is only 6 mm. wide, texture firm, with strong fibrous veins; the margins unarmed for the lower 8 cm., on the lower third the margins with ascending brown-tipped, subulate teeth 2–3 mm. long, 2–13 mm. apart, at the middle unarmed on one margin, but on the other with similar teeth, appressed and 9–17 mm. apart, near the apex the teeth ascending, 0.2–0.5 mm. long, 3–7 mm. apart, midrib unarmed; *pistillate inflorescence* single and apparently terminal; peduncle 19–20.5 cm. long, 7–12 mm. in diameter, trigonous, with numerous leafy bracts up to 95 cm. long, 10–14 mm. wide, long tapering to a subulate tip; *syncarp* 10 cm. long, 7.5 cm. in diameter, ovoid, obtusely subtrigonous, drupes about 140, crowded, the upper ¼ exposed; *drupes* 2.5–2.8 cm. long, 1.2–1.3 cm. wide, 1 cm. thick, the base 5–10 mm. wide, the body narrowly obovoid, color not recorded, on drying the smooth epidermis exfoliating and exposing the numerous longitudinal fibers, apical concavity partly filled by a darker brown, pillow-

[1] B. P. Bishop Museum, Honolulu 17, Hawaii. Manuscript received December 12, 1959.

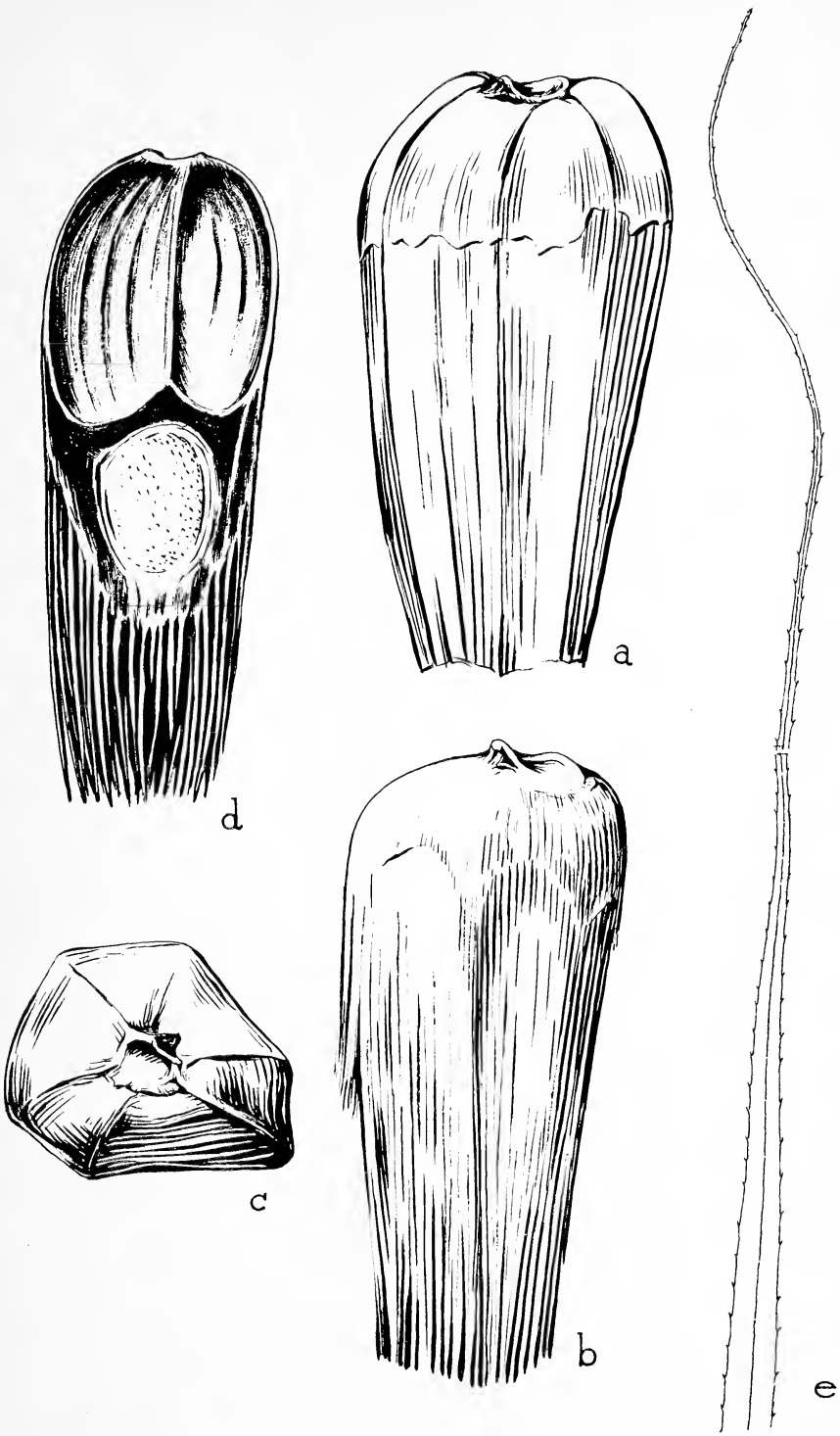

FIG. 9. *Pandanus kimberleyanus* St. John, from holotype. *a, b, c, d,* Drupe × 2⅔; *e,* leaf tip × ⅔.

like swelling; stigma 2 mm. wide, narrow lunate, on the margin of the concavity, excentric; endocarp slightly submedian, dark brown, bony, the outer wall 1.5 mm. thick; seed cavity 7 × 5.5 mm.; apical mesocarp one large cavity; basal mesocarp fleshy and strongly fibrous; *staminate inflorescence* leafy bracts almost unarmed; tip of inflorescence 4.5 cm. long, lateral spikes 1.5–2.5 cm. long; staminal columns 4–7 mm. long, stout, antheriferous in upper third, bearing about 7 anthers, free filament tips 0.3–1.3 mm. long; anthers 1.8–2 mm. long, 0.3 mm. wide, narrowly oblong, the base subsagittate, the apex apiculate.

HOLOTYPUS: Western Australia, West Kimberley, Fitzroy River, Aug. 1906, *W. V. Fitzgerald 2,395,* fruiting specimen, (NSW).

SPECIMENS EXAMINED: Western Australia, West Kimberley, mixed with the holotype, but a staminate inflorescence (NSW); Denham River, Oct. 1906, *W. V. Fitzgerald 1,625* (PERTH).

DISCUSSION: The specimens here described as new have been identified as *P. aquaticus* F. Muell., which species was first published by von Mueller in 1856 as a provisional species. Later, in 1865, he accepted and validated it with a description which included no more than that the plants were small and slender, lacked aerial roots, and had separate drupes. Bentham received from von Mueller only leaves and a staminate inflorescence, so could not fully document the species. Warburg saw no more and considered the species dubious. Martelli mentioned no specimens but listed the species. Blake (1954: 131) considered it to be the same as, and an earlier name for, *P. de-Lestangii.* The type locality of *P. aquaticus* was upper Victoria River, Northern Territory, and that of *P. de-Lestangii* Martelli was Burketown, n. w. Queensland. Blake considered that there was only one such species in northern Australia, reduced *P. de-Lestangii* to synonymy, and accepted *P. aquaticus* as the correct name. The present writer found in the Melbourne herbarium *P. aquaticus* F. Muell., from upper Victoria River, Dec. 1955, F. v. Mueller. The specimen consists of only a single leaf. It seems to be the holotype or an isotype. The one at Kew is little better, and the description was inadequate. After much field experience, it is realized that numerous species may grow side by side, and that geographic proximity of collections is not enough basis for reducing taxa to synonymy in this genus. It seems better to concur with Bentham and with Warburg and to continue to place *P. aquaticus* F. Muell. with the imperfectly known species. *P. de-Lestangii* Martelli was adequately described and illustrated from fruiting material, and staminate material is also known. This species is known to occur from the Daly River, Northern Territory, to the Gregory River, northwest Queensland. Fitzgerald (1918: 110) treated this species as *P. aquaticus* in his check list. Besides the two localities from which specimens were seen, he also gave the additional localities: Isdell, Charnley, and King River.

P. de-Lestangii Martelli, of the section *Microstigma,* has drupes 3.5–4.3 mm. long, stigmas apical, oblique, suborbicular, 1–3 in number; syncarp 10–13 cm. in diameter; leaves 4.5–8 cm. wide. *P. kimberleyanus,* of the same section, has drupes 2.5–2.8 cm. long; stigma narrowly lunate, excentric on the margin of the apical concavity; and leaves 3.7 cm. wide.

The new specific epithet is a geographic adjective, made from the name of the well-known Kimberley district where the plant occurs.

Pandanus convexus sp. nov. (sect. *Pandanus*)
Fig. 10

DIAGNOSIS HOLOTYPI: Arbor 10 m. altus, *phalangibus* (unam vidi) 6.3 cm. longis 6.6 cm. latis 5.2 cm. crassis late cuneatis in basi truncatis, lateribus planis levibus lucidis parte tertia superiore libera, sinibus lateralibus inter carpellas plerumque tam longis quam parte libera, angulis lateralibus minoribus et paucis, apice alto-convexa, carpellis 8, apicibus carpellarum depresso-convexis, sinibus centralibus 1.5–3 mm. profundis, stigmatibus 4–5 mm. longis subcentralibus suborbicularibus centripetalibus cordatis horizontalibus, endocarpio submediali 47 mm. longo 54 mm. lato magno obscure brunneo osseoso, seminibus 16–17 mm. longis 4–4.5 mm. diametro ellipsoideo, mesocarpio apicali cum cavernis parvis remotis medullosis et cum fibris, mesocarpio basali minimi fibrosi et carnosi.

DESCRIPTION OF ALL SPECIMENS EXAMINED: Tree 10 m. tall; trunks usually several together,

bi- tri-furcated near the summit; leaves 1.7 m. long, 6.7 cm. wide, lance-ligulate, long tapering; the marginal teeth at base few and small; the median teeth 2–4 mm. long, 5–12 mm. apart, acicular, appressed ascending, the larger ones red brown at tip; the teeth near the apex 0.2–1 mm. long, 5–12 mm. apart; midrib below with strong, retrorse prickles 3–4 mm. long, 12–25 mm. apart, red brown; *syncarps* "6–9 in. in diam., globular, red," *phalanges* 5.9–6.3 cm. long, 6.6–7.9 cm. wide, 5.2–7.6 cm. thick, "red," broad cuneate, the base truncate, the sides plane, smooth, shining, upper ⅓ free, the lateral sutures between the carpels as long as or shorter than the upper free part, lateral angles few and low, apex high convex; carpels 8–9, each apex low convex and with a radial suture line from the sinus to the stigma; inner sinuses 1.5–3 mm. deep; stigmas 4–5 mm. long, nearly central, suborbicular cordate, horizontal, flush, centripetal; endocarp slightly submedian, 47 mm. long, 54 mm. wide, massive, bony, dark brown; seeds 16–17 mm. long, 4–4.5 mm. in diameter, ellipsoid; apical mesocarp with small remote caverns which have longitudinal fibers and pithy cross partitions; basal mesocarp very small, fibrous and fleshy; *staminate inflorescence* 15.5 cm. long, 3 cm. diam., compact ellipsoid, with bracts 3–6 dm. long, 2–2.5 cm. wide, foliaceous, the margins entire; lateral spikes 1.5–3 cm. long, dense; stamens racemose; *anthers* 4.5–6 mm. long, linear sagittate, acuminate.

HOLOTYPUS: Western Australia, Dillens Springs, Oct. 1906, *W. V. Fitzgerald 2,394* (SYD).

SPECIMENS EXAMINED: Western Australia, Dillens Springs, Oct. 1906, *W. V. Fitzgerald 2.394* (the staminate inflorescence mixed with the holotype) (SYD).

Northern Territory: Escape Cliffs, *Hulls* [an error for *W. Hulse*] (Mel).

DISCUSSION: This species is known from meager collections, but it seems amply distinct by its phalanges with 8–9 carpels, small remote

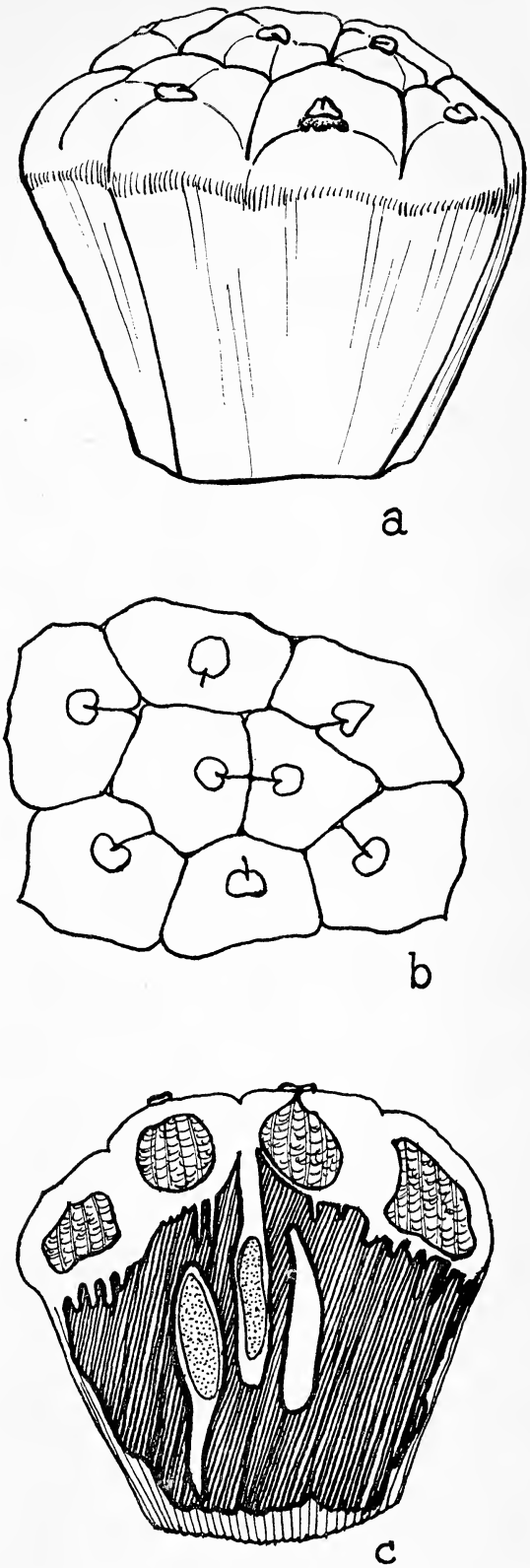

FIG. 10. *Pandanus convexus* St. John, from holotype. *a, b, c,* Phalange × 1.

apical mesocarp caverns, and the massive endocarp filling 5/6 of the interior. The related *P. spiralis* R. Br., described from the Wellesley Group, Gulf of Carpentaria, Queensland, has the phalanges with 16–22 carpels, the apical mesocarp caverns contiguous and ¼ as long as the phalange; and the endocarp ½ as long as the phalange and consisting of narrow, mostly separate bands.

The type locality is listed by Fitzgerald (1918: 220) as Dillen's Springs, spelled with an apostrophe. The locality is about 47 mi. south of Wyndham in East Kimberley and at approximately 16° S., 128° E.

The collector of the specimen from Escape Cliffs was published by Bentham (1878: 149) as Hulls. This was an error. The collector's name was really W. Hulse, as indicated by F. von Mueller (1869: 20).

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NOTES ON THE SECTION FOULLIOYA

In the preceding Part 1, the section Foullioya Warb. was listed but was omitted from the key. It should be inserted as follows, on p. 3, replace the second D, by:

D. Stigmas narrower than apex of drupe,
  a. Stigmas lunate, lateral under a horizontal coriaceous, entire or lobed visor borne asymmetrically on the apical region of the drupe but not marginal; syncarp solitary, cylindric, enwrapped in boat-shaped colored bracts; staminate flowers unknown ..... *Maysops*
  a. Stigmas deeply 2-lobed, tonguelike or reniform and 2-lobed, terminal, ascendings arcuate; syncarps several, globose to broad ellipsoid, with a single bract, exposed; stamens few, fascicled at apex of column ..... *Foullioya*

The genus *Fouilloya* Gaud., when published in 1841, contained illustrations of the two following species:

First, *F. maritima* Gaud. It was suggested by Brongniart (Ann. Sci. Nat. Bot. VI, 1: 291, 1875), that the type of this came from Madagascar or Mauritius. Later, Vaughan and Wiehe (Linn. Soc. Bot. J. 55: 20, 1953), report no living species on Mauritius that agrees with it and no evidence that it previously existed there. It has not been rediscovered elsewhere, but all its close relatives are native to Madagascar. It was renamed *Pandanus maritimus* Solms (1878), but this is a later homonym of *P. maritimus* Thouars (1808). So, this species has not been rediscovered since its publication in 1841, its homeland is unknown, and the specific epithet is unavailable in *Pandanus.*

Second, *F. racemosa* Gaud. Solely upon this was founded *Pandanus racemosus* Kurz (1869). It has not been rediscovered, and is known only from the Gaudichaud illustration and his specimen. Its homeland is unknown, but its relatives occur in Madagascar.

The group was first validly published as the section *Foullioya* (as *Fouilloya*) by Warburg

(1900), emend. Pic.-Ser. (1951). He included and accepted the two species first announced by Gaudichaud (1841) and added the two following:

P. Boivini Solms (1878) was described from a staminate flowering specimen, collected in Madagascar. The pistillate material for this species has not yet been discovered.

P. pygmaeus Thouars (1808), a Madagascar species represented by several recent collections, and by illustrations.

In choosing a lectotype one would normally prefer one of the two species that Gaudichaud included when he originally published the group as a genus. But, both of these are known only by the figures of the fruit given by Gaudichaud and by his scanty type specimens at Paris, and their nativity is unknown. Either of them would be unsatisfactory as a type. Consequently, depending on the fact that the genus when published by Gaudichaud was bitypic, and was without description, and was thus invalid, it is permissible to bypass them. Of the four original species in the valid section *Foullioya* Warb. emend. Pic.-Ser., only one is well known, of known origin, and still extant. Consequently this species is here chosen as, lectotype: *P. pygmaeus* Thouars.

Errata

The drawings for St. John's "Revision of the Genus *Pandanus* Stickman, Part 1," which appeared in Pacific Science 14(3): 224–241, were reduced to sizes which did not agree with the measures indicated in the legends.

Newly-written legends, which correct the errors, are presented herewith.

FIG. 1. *Pandanus biakensis*, from the holotype. *a*, Leaf base underside, × 5/11; *b*, leaf base margin, × 1.8; *c*, leaf middle underside, × 5/11; *d*, leaf tip underside, × 5/11; *e*, phalange, lateral view, × 5/11; *f*, phalange, longitudinal median section, × 5/11; *g*, phalange apex, × 1.8.

FIG. 6. *Pandanus conicus*, holotype. *a*, Phalange, lateral view, × ¾; *b*, phalange, longitudinal median section, × ¾; *c*, phalange, apical view, × ¾; *d*, carpel apices and stigmas, an inner one at lower right, and three outer ones, oblique view, × 3; *e*, leaf base, lower side, × ¾; *f*, leaf middle, lower side, × ¾; *g*, leaf tip, lower side, × ¾; *h*, leaf tip, lateral view, × ¾; *i*, leaf tip, lateral view, × 3.

FIG. 7. *Pandanus cochleatus*, from holotype. *a*, Phalange, lateral view, × ¾; *b*, phalange, longitudinal median section, × ¾; *c*, phalange, apical view, × ¾; *d*, carpel apices and stigmas, an inner one at left, and two outer ones, oblique view, × 3; *e*, leaf base, lower side, × ¾; *f*, leaf middle, lower side, × ¾; *g*, leaf margin at middle, × 3; *h*, leaf apex, lower side, × ¾.

FIG. 8. *Pandanus Zea*, holotype. *a*, Younger syncarp, × 3/14; *b*, mature syncarp, × 3/14; *c*, lateral drupes from above, × ¾; *d,e*, lateral drupes, from above, × 3; *f*, lateral drupe from side, × 3; *g*, lateral drupe from side, × ¾; *h*, lateral drupe from side, × 3; *i*, lateral drupe, longitudinal median section, × 3; *j*, apical drupes, from above, × ¾; *k,l*, apical drupes, from above, × 3; *m*, apical drupe, oblique lateral view, × 3; *n*, apical drupe, lateral view, × ¾; *o*, apical drupe, lateral view, × 3; *p*, apical drupe, longitudinal median section, × 3; *q*, leaf base, lower side, × ¾; *r*, leaf middle, lower side, × ¾; *s*, leaf apex, lower side, × ¾.

Fungi from Raroia in the Tuamotu Archipelago

William Bridge Cooke[1]

Between July 21 and September 6, 1952, M. S. Doty collected a number of specimens of fungi on Raroia (ca. 16°05′ S., 142°25′ W.) in the Tuamotu Archipelago. These were sent to the writer for identification. In turn, certain specimens were forwarded to specialists for more accurate identification than the writer could furnish.

The geographic distribution of the fungi of the islands in the Pacific Ocean is poorly known, largely because usually only the more obvious things, such as *Pycnoporus sanguineus,* are collected. It is probable that the fungi of the Tuamotus have never before been collected as thoroughly as they were on Dr. Doty's visit.

There are few habitats on an atoll for fungi. These are largely the dead wood of native or introduced trees, and driftwood.

In addition to the seven species reported below, based on material in 19 collections, other species were found. However, some specimens were unidentified because they were immature at the time of collection, had passed maturity and were no longer producing spores, or were poorly dried because of inadequate drying facilities.

The writer wishes to acknowledge the help of B. Lowy, J. H. Miller, L. E. Wehmeyer, John Eriksson, S. J. Hughes, J. A. Stevenson, and J. L. Lowe, in identifying this material. Duplicate specimens of all species listed have been forwarded to the Bishop Museum, Honolulu; and the National Fungus Collections, Beltsville, Maryland. Duplicates of several species were sent to the New York Botanical Gardens.

ASCOMYCETES

Anthostomella sp.

On fallen rachis of leaf of *Cocos nucifera.* 11274, 11277. July 21, 1952. 11277 is older than 11274 and has more crowded perithecia. Dr. L. E. Wehmeyer stated that these specimens have the spores of *A. melanosticta* but that this species shows no surface blackening. Additional species which are similar include *A. contaminans* (Dur. & Mont.) Sacc., and *A. lugubris* (Rob. & Desm.) Sacc. The description of *A. cocoes-capitatae* Cab. was not available at the time of examination.

Hypoxylon chrysoconium Berk. & Br.

Six collections were made from decaying wood of *Guettarda speciosa* or *Messerschmidia argentea.* 11279, 11280, 11374, 11389, 11390, 11393. July 21, 28, 29. Dr. J. H. Miller stated that "this is intermediate with *Rosellinia* but the perithecia are often united into an effused stroma. It occurs from India through the Hawaiian Islands." The mycelium on the surface of the wood is golden in color, making the species readily identifiable in the field. Two specimens were without perithecia and so were identified by analogy.

Hypoxylon investiens (Schw.) Berk.

Three specimens were obtained from decaying wood of *Guettarda speciosa* or *Messerschmidia argentea.* 11267, 11273, 11606. July 21, August 7. Dr. Miller indicated that the specimens were rather old, showed few perithecia, and that blackening of the wood was characteristic of the species. This species forms thin, brown, effused patches on decaying twigs, branches, and wood.

Phaeopeltosphaeria irregularis Wehmeyer

Two specimens of this species were found on old wood, probably drift wood. 11164, 11394. July 9, 28. Dr. Wehmeyer indicated that this species has now been found on three atolls of the Marshall Islands and on the Galapagos Islands. He said that "it is apparently common in the South Pacific on driftwood."

[1] Robert A. Taft Sanitary Engineering Center, Bureau of State Services, Public Health Service, U. S. Department of Health, Education, and Welfare, Cincinnati, Ohio. Manuscript received January 18, 1960.

BASIDIOMYCETES

Auricularia mesenterica Pers.

Three collections of this widely distributed tropical species were taken from wood of *Messerschmidia argentea.* 11262, 11386, 11661. July 21, 28, August 8.

Schizophyllum commune Fr.

Although the shape of the specimens obtained by Doty is typical of more northern material usually assigned to this species, this specimen could as easily have been placed in *S. radiatum* (Swartz) Fries[2] because of its tropical distribution. Throughout the Pacific Basin only one species is recognized in this genus at present. 11425. July 26.

Thirteen collections of thelephoraceous fungi were sent to John Eriksson for identification. Unfortunately, Dr. Eriksson was unfamiliar with the species these collections represent. In addition, the methods of preservation of these specimens make their identification quite difficult. Representatives of *Peniophora* sect. *Coloratae,* and sect. *Hyphales* were present. No spores and no fertile fruiting structures were present in the collections, although in some cases holobasidia were observable. It was suggested that through habitat, knowledge of sterile hymenial structures, and other features of a collection, a person familiar with tropical species in this group could make tentative identifications.

The same difficulties were found in the several collections of pore fungi which were made. A large trametoid specimen, a medium-size black *Phellinus*-like species represented by two normal specimens and two overgrown with a *Peniophora*-like species, and nine specimens of resupinate polypores were among the materials obtained. Because of his wide familiarity with tropical polypores these specimens were submitted to John A. Stevenson, National Fungus Collections, for study. The writer had found no satisfactory basidial or spore characters and hoped that sight identification might be possible. Neither Mr. Stevenson, nor Josiah L. Lowe who also examined them, could come to any conclusion concerning species names for these specimens.

The collection and adequate preparation of specimens of this type in tropical regions is difficult. It has been suggested that if quick drying equipment is not readily available, the hymenia should be inverted to prevent loss of spores during drying. Care should also be taken to prevent the specimens from getting too wet during periods of prolonged rain or high humidity. This condition tends to reactivate the hymenial tissues and exhaust the spore-producing capacity of the basidia, which then become unrecognizable structures.

FUNGI IMPERFECTI

Helicomyces roseus Link

Two specimens composed of pieces of wood partially covered with a white effused growth were assigned to this species. Spores from this white growth were very similar to those described by Linder (Ann. Mo. Bot. Gard. 16: 271, 1929) for this species. The material was assigned to this species on that basis as well as on the fact that it resembles closely material described under this name by Rogers (Pacif. Sci. 1: 106, 1947), from the Marshall Islands. Dr. S. J. Hughes did not agree with this identification but offered no substitute. 11283, 11602. July 21, September 6.

Helicosporium lumbricoides Sacc. em. Matr.

Two collections were made from material on old spathes of *Cocos nucifera.* 11269, 11270. July 21. Identification by S. J. Hughes.

Oidium curtisii (Berk.) Linder

Found twice on rotten wood. 11385, 11400. July 28, 29. Identified by S. J. Hughes.

Additional collections of moldlike fungi were found to be sterile, or when spores were present it was difficult or impossible to determine the method of their production, so that they were unidentifiable.

On the basis of the material seen, both that listed above and that which proved to be unworkable, it would seem that a considerable

[2] Now considered to be synonymous with *S. commune.*

number of fungus species is at work reducing the dead organic matter of the Pacific islands to humus and mineral material. In addition to fungi of these types there are also plant pathogens, soil molds, and probably aquatic fungi on land, and marine fungi parasitizing algae and growing on the ocean floor, especially where there is decaying wood. Recent work in the North Atlantic indicates that there is a population of fungi in marine sediments to considerable depth.

According to the unidentifiable material in Doty's collections, there are several species of polypores, thelephores, and agarics in the mycobiota of Raroia. In addition there are other types of molds associated with wood. In collecting such fungi great care must be exercised in the drying process to insure against the secondary invasion of mold fungi in the tissues and sporiferous areas of the sporophore. It is hoped that additional collections will be made in the Pacific Basin in order that the fungal populations and their activities may become better known.

Notes on Indo-Pacific Scleractinian Corals, Part 3
A New Reef Coral from New Caledonia

JOHN W. WELLS[1]

IN 1957 Dr. R. L. A. Catala of the Station de Biologie Marine, Nouméa, New Caledonia, discovered the brilliant fluorescence in ultraviolet light of the polyps of reef corals living in deeper waters (see, Nature 1(83): 949, 1959; Life 47(3): 64–65, 1959; 26 franc postage stamp of New Caledonia issued March 21, 1958). Dr. Catala kindly sent the writer a collection of these corals, together with photographs of many of them living in the Aquarium de Nouméa. The specimens came from a depth of 35–40 m. on Banc Gail, in the lagoon of Nouméa about 10 mi. from the Aquarium, and were collected by Dr. Yves Merlet, for whom the new species described below is named. The scleractinian fauna includes these species:

Montipora caliculata (Dana)
M. verrucosa (Lam.)
Goniopora lobata Milne Edwards & Haime
Favia speciosa (Dana)
Favites abdita (Ellis & Solander)
Platygyra lamellina (Ehrenberg)
Echinopora hirsutissima M. E. & H.
Trachyphyllia geoffroyi (Audouin)
Galaxea fascicularis (Linn.)
Bantamia merleti sp. nov.
Cynarina lacrymalis (M. E. & H.)[2]
Protolobophyllia japonica Yabe & Sugiyama[2]
Lobophyllia corymbosa (Forskaal)
L. hemprichi (Ehrenb.)
Symphyllia recta (Dana)
Mycedium elephantotus (Pallas)
Euphyllia picteti Bedot[3]
Plerogyra sinuosa (Dana)

[1] Department of Geology, Cornell University, Ithaca, New York. Manuscript received February 1, 1960.

[2] These two species will be the subject of a subsequent note.

[3] Photographs by Dr. Catala of the living coralla of this species show an exact similarity, including color, between its polyps and those of *Pectinia jardinei* Saville-Kent (1893: 39; 1958: pl. 25, fig. 3, and chromo pl. 4, fig. 7) from the northern part of the Great Barrier Reef, and this form probably should be termed *Euphyllia jardinei* (Saville-Kent). *E. picteti* was originally described from Amboina by Bedot and has been reported by the writer (1955: 26) from Port Newry, Queensland.

FAMILY OCULINIDAE

SUBFAMILY GALAXEINAE

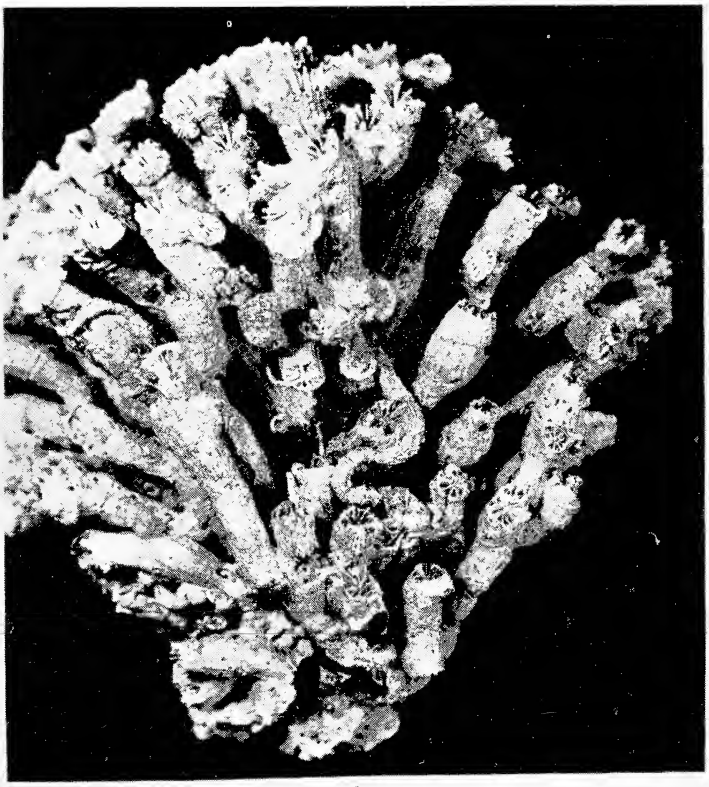
GENUS *Bantamia* Yabe & Eguchi 1943

Bantamia merleti sp. nov.
Figs. 1–4

Corallum fasciculate, 10 cm. in height, 10 cm. broad (holotype), formed by cylindrical corallites, 5–7 mm. in diameter, 4–7 mm. apart, arising by extratentacular budding from a very narrow edge-zone near the calices, at first subhorizontal, then becoming erect and subparallel and losing organic connection with parents. Exterior of corallites costate only near calices, epithecate below, completely lacking any exothecal structures. Calices circular or slightly compressed, 5–7 mm. in diameter, shallow. Septa exsert 1–1.5 mm. near the wall, dropping to low inner lobes near the columella. Septal margins thickened where exsert, nondentate but finely granulated, the granulations extending down septal sides where they are evenly distributed. Septa of first two cycles (12) equal and extending to columella; a few very thin, short septa of the third cycle developed in some systems. Costae weakly developed by narrow edge-zone near calices; in some corallites the edge-zone is not developed and the wall appears epithecal. Columella formed by interlaced loose trabecular processes from inner margins of septa, with one to three granulate papillae arising in bottom of the calice and commonly having a sublamellar aspect. Endotheca consisting of widely spaced, deeply concave single vesicles, the latest ones about 5 mm. below bottom of calice.

Polyps pale brown with pale yellow-green peristomes. Peristomes fluorescing a pale emerald green, the remainder a pale orange-brown.

The reference of this species to *Bantamia* is fairly certain on the basis of Yabe and Eguchi's careful description of the unique specimen of *B. gerthi* from the Miocene deposits of Java. *B. merleti*, also known from a unique specimen, lacks the feeble development of vesicular exo-



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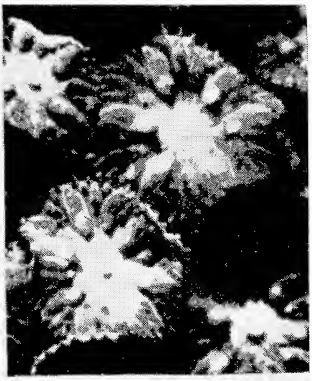

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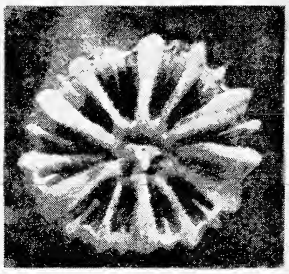

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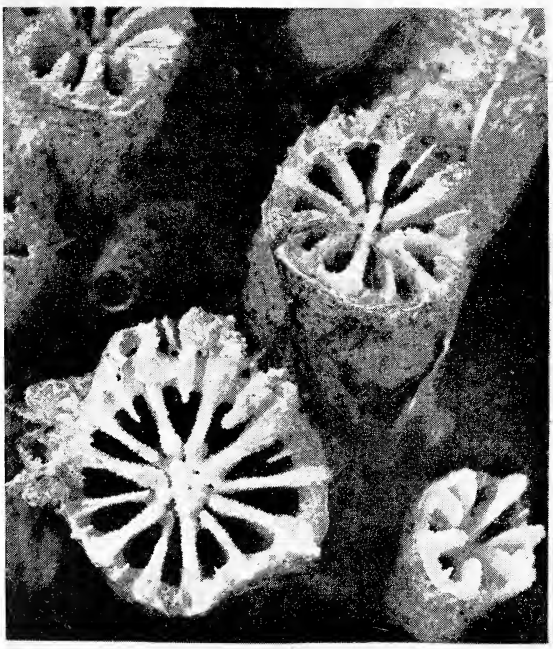

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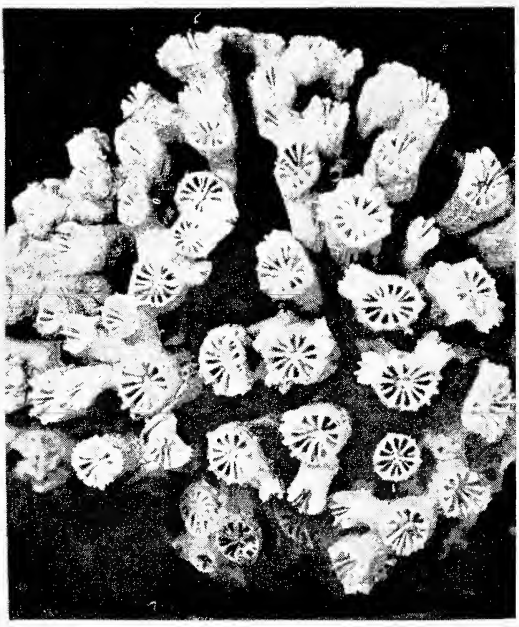

2

theca found in the angles of the branches, has fewer septa in the adult corallites, and has concave rather than tabulate endothecal dissepiments. The range of *Bantamia* thus appears to be extended from the Miocene time to the Recent epoch. *B. merleti* is apparently not a surface reef type but is confined to the deeper lagoon waters.

Yabe and Eguchi considered *Bantamia* to be closely related to *Galaxea*, differing only in the almost complete reduction in *Bantamia* of the extensive vesicular endotheca of *Galaxea* (or the converse?). This skeletal difference implies an almost complete lack of edge-zone in the polyps of *Bantamia*, a distinction confirmed by *B. merleti*. The striking similarity of the calice, septa, and columella of the two genera is emphasized by comparison of the calices of *B. merleti* (Fig. 3) and *G. fascicularis* (Fig. 5). On the other hand, a color photograph by Catala of the living holotype colony of *B. merleti* indicates a considerable difference in the polyps of the two genera. This is not clearly shown in the enlargement (Fig. 4), for the polyps are evidently not fully expanded. According to Fowler (1890: 409) and Matthai (1914: 59), the tentacles of *Galaxea* are ento- and exocoelic, arranged in two rings of 12 each around the prominent (when expanded) oral cone. Saville-Kent (1893: chromo pl. 4, figs. 8–12) and Yonge (1930: 24, fig. 10) show them in a single ring near the edge of the oral disc, the 6 over the first cycle septa standing erect around the oral cone, the 6 of the second cycle and the 12 of the third cycle smaller and normally pointing outwards. The polyps of *Galaxea* are usually partly expanded even in daylight. In *B. merleti* the tentacles total 96, arranged in five alternating rings over the outer half of the oral disc, in the center of which is a small protuberant oral cone. It would appear that the inner three rings, totaling 24 tentacles, are entocoelic, overlying the entocoeles of the mesenterial couples containing the first two cycles and developed parts of the third cycle of septa, in decreasing order of size. The next 24 tentacles, near the periphery, are also entocoelic without corresponding fourth cycle septa. The outer marginal ring of 48 small tentacles is probably exocoelic and extends like a fringe around the edge of the oral disc.

The external morphology of the living reef corals is not yet well enough known to evaluate the taxonomic worth of such differences in tentacular number and arrangement.

Holotype to be deposited in the U. S. National Museum.

Locality: 35–40 m. depth, Banc Gail, Nouméa lagoon, New Caledonia.

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FIGS. 1–4. *Bantamia merleti* n. sp. 1, 2, Lateral and calicular aspects of holotype corallum, ×1; 3, calices, ×4; 4, partially expanded polyps of holotype, ×4 (from color photo by R. Catala).

FIG. 5. Calice of *Galaxea fascicularis* (Linn.), Amboina, ×8 (Bedot, 1907: pl. 11, fig. 44).

Porifera of Friday Harbor and Vicinity

M. W. de Laubenfels[1]

The Porifera of the northwest coast of North America were described rather thoroughly in three papers by L. M. Lambe (1892, 1893, 1894). Many sponges which he treated were from Vancouver Island, near the location herein discussed. Otherwise the Puget Sound Porifera have been little studied.

The present paper is based on a study made by the author during the summer of 1931. Intertidal species were studied living, in the field. Dredged specimens were examined practically immediately upon removal from the water. T. G. Thomson, director of the Oceanographic Laboratories at that time, and other members of the staff, rendered valuable cooperation for which gratitude is hereby expressed.

While other invertebrates were found in considerable variety, amazingly few species of sponges were found to occur in the San Juan Archipelago. The number of individual specimens was large, so that one may conclude that conditions were suitable for the survival and growth of sponges. Notwithstanding careful search of the shores and almost daily dredging for several weeks, the collection consists of representatives of 16 genera, 17 species in all, 2 of which, *Stylissa stipitata* and *Syringella amphispicula*, are new to science. Two species of the class Calcispongiae were found. No dredging was done deep enough to bring up sponges of the class Hyalospongiae. The 15 species of the class Demospongiae represent 14 genera.

CALCISPONGIAE

Leucosolenia nautilia de Laubenfels, 1930

The sponge thus identified was collected July 4, 1931, near the town of Lopez in Lopez Island. It was dredged from a depth of about 60 m.

It consists of a mass of tubes, each somewhat less than 1 mm. in diameter, occasionally anastomosing, but much more frequently branching. The mass of tubes arises from a basal rhizome or reticulation of tubes affixed to the substratum. The maximum distance from this which is reached by the ascending or descending tubes is barely 1 cm. The color in life was white; the consistency softly fragile. The occasional oscules are located at the distal extremities of the ascon tubes and are less than 1 mm. in diameter. The surface is optically smooth, and microscopically somewhat roughened by spicules which protrude, but not at right angles, they lie tangentially in the ectosome, their points directed toward the oscule. Around the oscule in each is found a coronal fringe of special oxeas about 6 $\times$ 300μ. The obliquely placed dermal oxeas are somewhat larger, say about 8 $\times$ 420μ. The principal spicules in among the flagellate cells of the ascon layer are triaxons with rays about 8 $\times$ 140μ. There are a few hypogastral quadriradiates, of approximately the same size as the triradiates.

This is the second record of this species, the first being by de Laubenfels (1930: 25) from Monterey Bay, California. The Puget Sound specimen has somewhat smaller oxeas echinanting the surface than do the California specimens, but otherwise it agrees very closely. The other species of *Leucosolenia* which is probably most closely to be compared here, and which therefore indicates the zoogeographical relationships of the form under discussion, is *Leucosolenia echinata* Kirk (1894: 177) from New Zealand. All its spicules are noticeably larger than those of *nautilia* and it is remarkable that in it the quadriradiates considerably exceed the triradiates in abundance. Furthermore, it is not recorded by Kirk that there were special coronal oxeas, although this may have been the case and they were overlooked by the author.

Scypha raphanus (Schmidt, 1862) de Laubenfels, 1936*a*

The species thus tentatively identified was found growing on the pilings at Friday Harbor.

[1] A posthumous paper, edited by Frank J. Little, Jr., Department of Zoology, University of Texas, Austin, Texas. Manuscript received February 11, 1960.

It is in the form of great pendants tapering at each end, and cylindrical in the central region. Common sizes range from 3 × 30 mm. to 8 × 50 mm. The color in life was dirty white but was considerably obscured by accumulations of foreign material on the surface. The consistency is somewhat elastic but in general very fragile. The surface is minutely hispid, minutely cavernous to the naked eye. The critical difference between this genus (frequently known as *Sycon*) and *Grantia* is in the presence or absence of a special dermis, which is present in *Grantia.*

The structure of the chambers is typically sycon, with elongate thimble shaped chambers frequently as large as 180 × 700μ, but in some portions of the surface shallow and cuplike in shape, in this case being about 130μ in diameter and only 100μ in depth. The oscules are about 2 or 3 mm. in diameter and to the naked eye have smooth rims without conspicuous coronal fringes. Microscopical study shows that coronal spicules are present; they are about 6 × 800μ. The spicules of the chamber layer include smaller oxeas about 5 × 400μ and abundant triaxons with rays 5 × 75μ to 6 × 105μ. Among them occur a very few tetraxons with cladomes of about the same size as the triaxons, but with rhabds considerably shorter. There are raphide-like spicules perhaps to be classified as microscleres. They are only 0.75μ in diameter and so frequently broken because of their delicacy that maximum lengths cannot satisfactorily be assigned.

Lambe (1893: 38) described a *Sycon* (that is to say, a *Scypha*) with specific name *compactum*, from this vicinity. Its dermal oxeas are very much smaller than those of the specimen here described, and the triacts of the chamber layer have shorter rays of the same thickness, but much more sagittal in shape. It possesses a conspicuous subgastral category of triradiates, and in its gastral quadriradiates the rhabds, instead of being shorter than the clads, are longer. Its shape, moreover, is thicker in proportion to the length than is true to the Friday Harbor sponge.

There are two species of *Sycon*, that is to say *Scypha*, described from California. *S. coronatum* was first placed in the genus *Spongia* by Ellis and Solander (1786: 190). It does not have any microxeas. *S. coactum* was described by Urban (1905: 55) as of the genus *Sycandra.* It does have microxeas, but does not have typical tufts to the flagellate chambers, that is to say, spicules projecting from the surface, as is true of the Puget Sound sponge. Furthermore, all the spicules of *coactum* are very much larger than those of *raphana.*

S. raphana was first described by Schmidt (1862: 14) from the Adriatic. There are many minute points of difference between it and the American sponge, but at least *pro tem* this identification may be made.

DEMOSPONGIAE

Haliclona permollis (Bowerbank, 1866) de Laubenfels, 1936*a*

The sponge thus identified was found growing abundantly in a channel at a beach near Argyle on San Juan Island. This was so placed that a strong current rushed past it each time the tide changed. The shape is encrusting with very conspicuous oscular projections. The color in life was a beautiful purple. The consistency is somewhat elastic but rather fragile. The surface, aside from the evident pores, is optically smooth. The oscular projections referred to are about 7 to 9 mm. high, each terminating in a round oscule about 2 mm. in diameter. The total projection, however, is much larger than this, frequently reaching a thickness of 4 or 5 mm. It is very unusual to find such conspicuous oscular tubes on a sponge placed in a strong current, although such are very common in sponges which grow in calm water. The pores are about 100μ in diameter and 200μ or 300μ apart, and as mentioned above, they show very plainly. The internal structure is an isodictyal or "renierid" reticulation of spicules united chiefly at their apices. These are of one sort only, oxeas approximately 7 × 100μ.

This species is clearly conspecific with that which Lambe (1893: 26) recorded from British Columbia and identified as *Reniera cinerea*, a name which unfortunately can no longer be employed, as was shown by de Laubenfels (1936*a*: 39). A lavender species of *Haliclona* of this general type is found in many places in the world. They are separated from each other only by such

items as minute differences in average length of spicule, and it may well be that they are really conspecific, although this is far from certain. From the majority of them the Puget Sound species differs in having considerably shorter spicules. Those of Europe and California, for example, are 140μ long, instead of only 100μ.

Xestospongia vanilla (de Laubenfels, 1930) 1932

The specimen thus identified was found growing intertidally on Brown Island, July 1, 1931. It is a thinly encrusting specimen, at most 2 or 3 mm. thick, and spreading indefinitely laterally. The color is a pale drab, and the consistency is almost stony hard. The surface is smooth and even except for the minute pores and an occasional oscule well under 1 mm. in diameter. The endosomal structure is very dense, the spicules being crowded close together, but permeated by canals which are arranged so frequently at right angles to each other that their pattern is that of a reticulation. The spicules are of one sort only, hastately pointed oxeas about 11 $\times$ 137μ. A few which are much smaller are possibly to be regarded as being not yet fully developed.

This species was originally described by de Laubenfels (1930: 28) as *Haliclona vanilla* and was transferred by him (1932: 116) to the new genus *Xestospongia* with a fairly complete discussion of the species and genus. The Puget Sound specimen is entirely typical, differing in no important respects from the common California species.

Sigmadocia edaphus (de Laubenfels, 1930) 1936*a*
Fig. 2*a*

The sponge so identified was collected on July 3, 1931, being dredged from a depth of 15 m. in Peavine Pass. Large masses aggregating several handfuls, amorphous in shape, were taken at this time. The color in life was pale drab, almost white, and the consistency is stony hard. The surface is comparatively smooth; microscopically it is seen to be abundantly provided with pores only a little more than 100μ in diameter. The oscules average about 10 mm. apart and are nearly 1 mm. in diameter. The interior is rather dense, but is somewhat breadlike in structure, without any conspicuous reticulation of canals. They are united in a somewhat isodictyal fashion, that is to say, connected to each other at their apices in such a way as to make triangular or polygonal meshes. Those immediately at the surface placed horizontally make a network of even finer mesh than that of the endosome. The megascleres of this sponge are of one type only, oxeas approximately 22 $\times$ 285μ. There is also one type of microsclere present, a sigma varying from 40μ to 66μ in length.

The Puget Sound specimen is in very complete agreement with the specimen described as *Gellius edaphus* by de Laubenfels (1930: 28) and discussed by him in more detail and compared to related species (1932: 111). The species was transferred to *Sigmadocia* by de Laubenfels (1936*a*: 69).

Lissodendoryx firma (Lambe, 1894) new transfer
Fig. 1, *A1*, *A2*, *A3*

The sponge thus identified was collected on July 3, 1931. It was dredged from a depth of 75 m. near Turn Island.

It is a compactly massive sponge, only 4 or 5 cm. in greatest diameter and in life was a rich orange color. The consistency is firm, somewhat elastic. The surface is slightly tuberculate, but in general might be described as smooth, a very evident special dermal reticulation being fine grained. The pores are minute and the oscules are represented only dubiously by a few openings much less than 1 mm. in diameter which possibly were mere accidental ruptures in the surface. The interior is dense, provided with only a small amount of open space in the form of canals or gross chambers. The special dermal tornotes are hastately pointed tylostrogyles 7 $\times$ 343μ. The principal skeleton is made up of a more or less confused dense mass of smooth styles, exceptionally large for this genus. They are 36 $\times$ 440μ. The microscleres include arcuate isochelas of one sort, length 43μ, and sigmas of one sort, length 30 to 32μ.

This species was first described as *Myxilla firma* by Lambe (1894: 122). It may appropriately be compared to *Lissodendoryx kyma* de Laubenfels, 1930 (p. 27). This California sponge lacks the sigmas, and all of its spicules are notably smaller than those of *firma*. It should be commented, however, that *kyma* and *firma* are remarkable in the genus for the exceptionally

large size of the spicules; they are doubtless related forms.

Lissodendoryx noxiosa de Laubenfels, 1930
Fig. 1, *B1*

The specimen thus identified was dredged on July 3, 1931, at a depth of 15 m., in Peavine Pass; masses aggregating several handfuls came up in the dredge.

The shape is amorphous and the color in life a dull yellowish drab. The characteristic unpleasant odor was very much in evidence in life, and seemed to be identical with the odor of the California specimens to the best of the recollection of the author. The consistency is softly spongy, fragile. The surface is irregularly tuberculate, but otherwise is optically smooth because the dermal skeleton is of very fine mesh. Rather numerous oscules are scattered about, averaging somewhat under 1 cm. apart, and 0.5 to 1.5 mm. in diameter.

The endosome is very much like the structure of a crumb of bread, the spicules being arranged primarily in bunches, but otherwise in a somewhat isodictyal reticulation in the masses surrounding the numerous gross chambers. The special dermal spicules may be described in general as being tylotes, but very frequently there is a rounded promulgation at each end, as though they were strongyles with a tylote enlargement near but not at each end. Others of them have one end larger than the other and the smaller end somewhat spined. The variety of shapes is quite remarkable. The endosomal spicules are smooth styles, with here and there what may be interpreted as an incipient spine. Only arcuate chelas 28μ were in evidence as microscleres.

This species was described by de Laubenfels (1930: 27) from California, where it is very abundant, and yet it is doubtful if any California specimen has attained the very large size of the Puget Sound one. Lambe (1894: 121) had a *Lissodendoryx* which he identified as *Myxilla barentsi* Vosmaer, 1885 (p. 27). This was almost certainly the form at present under discussion and not the arctic species of Vosmaer. Lambe's specimen had as its principal spicules styles with small spines on them. Whereas this is not common, it is really the case in the Peavine Pass specimen and various California specimens also show this tendency. Lambe's specimen had sigmas, as do the California specimens. The latter variety has megascleres about thirty percent shorter but not thinner than those of the Puget Sound sponges. Taken by itself alone, this is a trivial difference. The general agreement, and especially the very distinctive odor render it possible to make the identification with *noxiosa* very confidently.

Burtonanchora lacunosa (Lambe, 1892) de Laubenfels, 1936*a*

The sponge thus identified was dredged on July 3, 1931, in Peavine Pass, at a depth of 15 m. It is a small subovate mass about 2 $\times$ 3 cm. The color in life was fleshy pink, and the consistency is softly spongy to fragile. The surface, otherwise smooth, is rendered irregular by the pore areas and oscules mentioned below. There is definite evidence of the presence of a special dermal layer. The round oscules are nearly 1 mm. in diameter and are scattered here and there more than 1 cm. apart in most places, but occasionally as little as 2 mm. apart. Except within regions about 2 or 3 mm. from the oscules, the entire surface of the sponge is dotted with pore areas each nearly 1 mm. in diameter and about 2 mm. apart, center to center. Each of these circular areas is a sieve with the pores approximately 100μ in diameter, and crowded closely together.

The endosomal structure is between subisodictyal and confused. The special dermal spicules are inequi-ended hastately pointed tornotes, about 7 $\times$ 220μ. The endosomal spicules are somewhat spiny styles 12 $\times$ 220μ. The microscleres include sigmas 23μ long, and isochelas slightly longer. The latter are here interpreted as being anchorate, but they are far from being typical anchorate chelas, verging strongly towards the arcuate.

Lambe (1892: 70) described a sponge from the vicinity of Vancouver as *Myxilla lacunosa*, which is rather clearly the form under discussion but which has one difference, i. e., that the principal spicules according to Lambe were not spiny. At the same time (p. 71) Lambe records another *Myxilla* which he identifies as being *rosacea* of Lieberkühn (1859: 521). This second specimen has the principal spicules like the Pea-

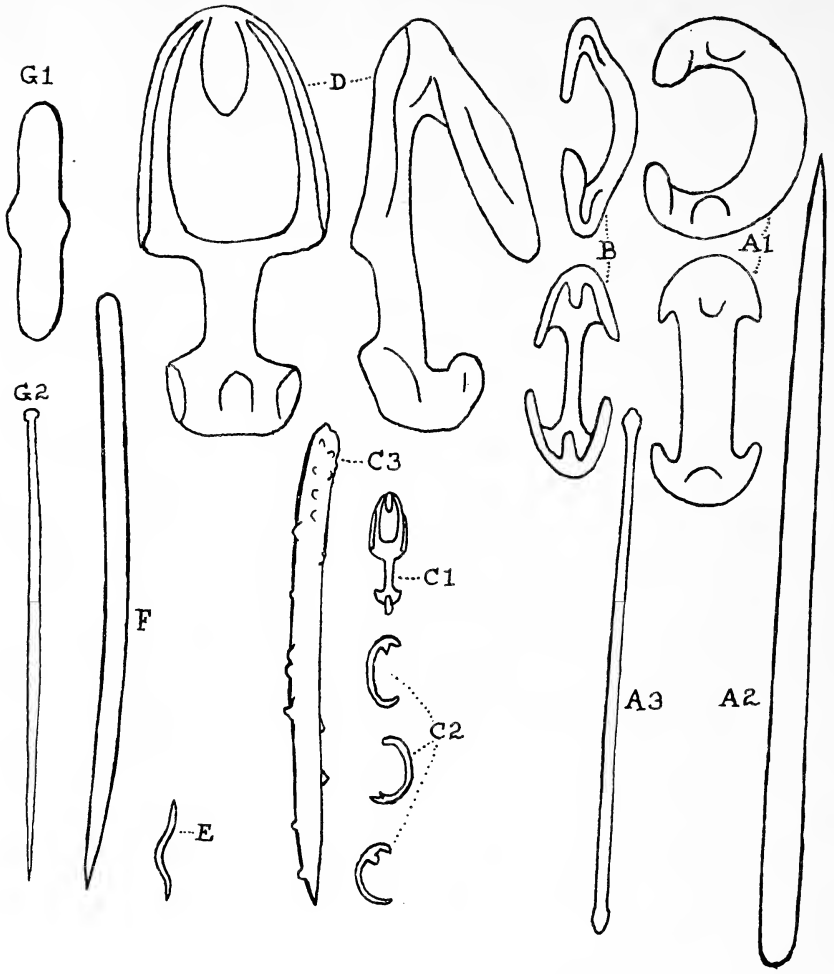

FIG. 1. *A, Lissodendoryx firma* (Lambe): *1,* chelas, × 880; *2,* style, × 212; *3,* dermal tornote, × 212. *B, Lissodendoryx noxiosa* de Laubenfels; chelas, × 880. *C, Iophon chelifer* var. *californiana* de Laubenfels: *1,* anisochela, × 212; *2,* bipocilli, × 212; *3,* acanthostyle, × 212. *D, Mycale adhaerens* (Lambe); anisochela, × 880. *E, Ophlitaspongia pennata* (Lambe); toxa, × 212. *F, Stylissa stipitata* new species; style, × 212. *G, Choanites suberea* var. *lata* (Lambe): *1, microstrongyle,* × 880; *2,* tylostyle, × 212. (All from camera lucida drawings.)

vine Pass specimen now being discussed. Its isochelas and sigmas were both, however, about double the length of those of his *lacunosa* and those of the Puget Sound sponge. It is very frequently the case in the Myxillinae that there are two categories of chelas, a larger and a smaller, and two categories of sigmas, a larger and a smaller. One or the other of these may be common while the other is rare. It may be that there exists in the vicinity of Puget Sound but a single species, properly to be termed *lacunosa*, having a full complement that includes larger and smaller chelas, and larger and smaller sigmas. It may be that in a specimen which Lambe described as *lacunosa* he found only the smaller microscleres, and in the one he identified as *rosacea* he found only the larger. It is here proposed that the specimen identified by Lambe as being *rosacea* should be dropped in synonymy to his *lacunosa*. Neither of these two specimens described by the latter author possesses the peculiar arrangement of the surface found in the

sponge from Peavine Pass, but Lambe (1894: 121) described from the vicinity of Alaska a sponge which he named *Myxilla behringensis*. The dermal spicules and microscleres are very like those of his *lacunosa*, and significantly the endosomal spicules vary from entirely smooth as in his *lacunosa* to spiny as in the specimen he identified as *rosacea*. This *behringensis* did have the peculiar arrangement of the pores and oscules of the specimens herein described. It seems probable that only one species is involved in all of these descriptions, and it is therefore proposed that *Myxilla behringensis* Lambe be dropped in synonymy to his *lacunosa*, which was transferred to the genus *Burtonanchora* by de Laubenfels (1936*a*: 94).

Ectyodoryx parasitica (Lambe, 1893) de Laubenfels, 1936*a*

This species is exceedingly abundant in the vicinity of Friday Harbor, occurring apparently always on the shells of bivalve mollusks belonging to the genus *Pecten*. In fact, practically every specimen of *Pecten* collected in this vicinity seems to have been utilized by the sponges. Usually the sponges are of this species, but occasionally *Mycale adhaerens*, to be described below, is also found on the shells. Two hundred and two such sponge-covered pectens were taken for study, and of them 183, or well over 90 per cent, proved to have *Ectyodoryx*. Nineteen had the *Mycale*. It was further noticed that in each case when both the valves of the pelecypod were abundantly covered with sponge, that the mollusk was always a male, though not all males were so distinguished.

The crust has a relatively smooth surface, although showing many openings such as pores and oscules. Thickness may attain to 12 or 15 mm., and lateral extent is of course limited by the size of the shell. The color in life is a dull grayish drab and the consistency is weakly spongy or fragile. The surface is abundantly covered with rather coarse pores and oscules about 1 mm. in diameter, irregularly scattered.

The endosome is "crumb-of-bread" in appearance and consistency. The special dermal spicules are hastately pointed tornotes, verging slightly upon the tylote shape. They are from 4 $\times$ 130μ to 6 $\times$ 145μ. The endosomal or principal spicules are styles, usually acanthose, about 11μ in diameter, but ranging in length from 190 to 270μ. Occasionally the spines are almost or completely wanting, which is very interesting in comparison to the preceding species, as is also the fact that there are two categories of isochelas present. These are anchorate, the larger being 54μ in length, while the smaller are only 14μ in length. There are also two sizes or categories of sigmas, each respectively about the size of the corresponding isochelas.

This species was originally described by Lambe (1893: 31) from Vancouver Island, as *Myxilla parasitica*. It was reviewed by de Laubenfels (1936*a*: 84) and its correct location in the genus *Ectyodoryx* was shown by him.

Tedania fragilis Lambe, 1894

The specimen thus identified was dredged northeast of Blakeley at a depth of between 50 and 66 m., on July 6, 1931. It is an encrustation less than 1 cm. thick, and about 2 $\times$ 4 cm. in area. In life it was flesh colored, and the consistency is very soft, fragile and compressible. The surface is comparatively smooth, almost glabrous. Pores and oscules can not be made out.

The endosome is rather dense to the unaided eye and microscopically is seen to be packed with plumose tracts, which is an axinellid characteristic usually not so pronounced in the genus *Tedania*. The special dermal tornotes are hastately pointed, 4 $\times$ 200μ. As may be expected the principal skeleton consists of styles, 3 $\times$ 150μ to 7 $\times$ 400μ, but it is most astonishing to note that some of these are more or less covered with small spines. The microscleres are onychaetes as is absolutely typical for the genus *Tedania*; these are long thin rhaphides 1 $\times$ 150μ to 3 $\times$ 200μ which are covered by characteristic roughenings, rather than pronounced spines.

A specimen which must surely have been conspecific with the one under discussion was described as *Tedania fragilis* by Lambe (1894: 116). It was a more typical *Tedania*, not possessing the unusual shape of the styles. Identification of the Puget Sound sponge with *Tedania* is rather confidently made, however, because of the very characteristic microscleres.

Iophon chelifer californiana de Laubenfels, 1932
Fig. 1, *C1*, *C2*, *C3*

The sponge so identified was dredged northeast of Blakeley on July 6, 1931, at a depth of between 50 and 66 m. It is an amorphous mass about 2 × 3 × 5 cm. In life it was a dull drab color, gradually turning black in alcohol. This is characteristic of the genus *Iophon*, and is exhibited by few, if any, other genera in quite the same way, i. e., some turn black suddenly upon exposure to air, etc. The consistency is softly fragile, crumbling. The surface is irregularly tuberculate, with a smooth dermal membrane much in evidence. This is broken off in many places, leaving numerous internal cavities exposed. It is difficult to say whether any oscules show or not; there are what appear to be oscules, but these may be merely places where the dermal membrane has been broken off, exposing the underlying cavities.

The interior is "crumb-of-bread" with an isodictyal reticulation of masses of spicules placed around minute cavities. The special dermal spicules are tylotes 4 to 7μ in diameter and 280μ long. The principal spicules are acanthostyles, reaching a maximum size of 16 × 320μ. The microscleres include palmate isochelas of the peculiar shape characteristic of the genus, and also bipocilli 13μ long, which resemble tridentate unguiferate anisochelas.

Ridley and Dendy (1886: 349) described *Iophon chelifer* and Lambe (1893: 30) recorded a sponge from the vicinity of Vancouver as of this species. There are differences from the typical race which were pointed out by de Laubenfels (1932: 82) in connection with specimens which he had from California, for which he established the subspecies *californiana*. The Puget Sound specimens correspond very closely with those from California, and one need have little hesitation in regarding them as of the same variety. It is very probable that the specimens described by de Laubenfels (1928: 361), as *Burtonella melanokhemia* are also conspecific with this variety of *chelifer*.

Ophlitaspongia pennata (Lambe, 1894) de Laubenfels, 1927
Fig 1, *E1*

This species was found growing on Brown Island, just across from the laboratory of the University of Washington. It is an exceedingly thin crust as found at Puget Sound, only 1 or 2 mm. thick, and spreading indefinitely laterally. The color at the time of collection was dull brown. The consistency is somewhat compressible, rather like that of soft wood. The surface is irregular with notable grooves radiating around minute oscules, only 200μ or 300μ in diameter.

The structure consists of innumerable little plumose columns extending up perpendicularly from the base and little if any connected to each other except by protoplasmic structures. The bulk of the spicules in these tracts are subtylostyles 16 to 20μ in diameter and about 330μ long. Near the surface many are found which are only 3 × 200μ; these may or may not constitute a separate category. Toxas about 40μ long are occasionally found among the smaller spicules near the surface.

This species was described as *Desmacella pennata* by Lambe (1894: 129). It is an exceedingly abundant sponge along the Pacific Coast of the United States, extending far down in California, almost to the Mexican boundary. It is noteworthy for its ability to survive intertidal conditions, often growing nearer the high tide mark than is true of other species of sponge. The species was transferred to the genus *Ophlitaspongia* by de Laubenfels (1927: 265). For a further discussion of the species, reference may be made to his paper on the sponges of California (1932: 103).

Mycale adhaerens (Lambe, 1893) de Laubenfels, 1936*a*
Fig. 1, *D1*, 2 B

This species occurs abundantly in the vicinity of Friday Harbor upon bivalve mollusks of the genus *Pecten*. As noted above in connection with *Ectyodoryx parasitica*, about 10 percent (or slightly less) of the *Pectens* in this vicinity have *Mycale* as the sponge which covers the shell.

The color in life is a dull grayish drab, and the consistency is softly spongy to fragile. The surface is nearly smooth, and what openings are found are susceptible to interpretation as being accidental ruptures in the dermis rather than structural oscules.

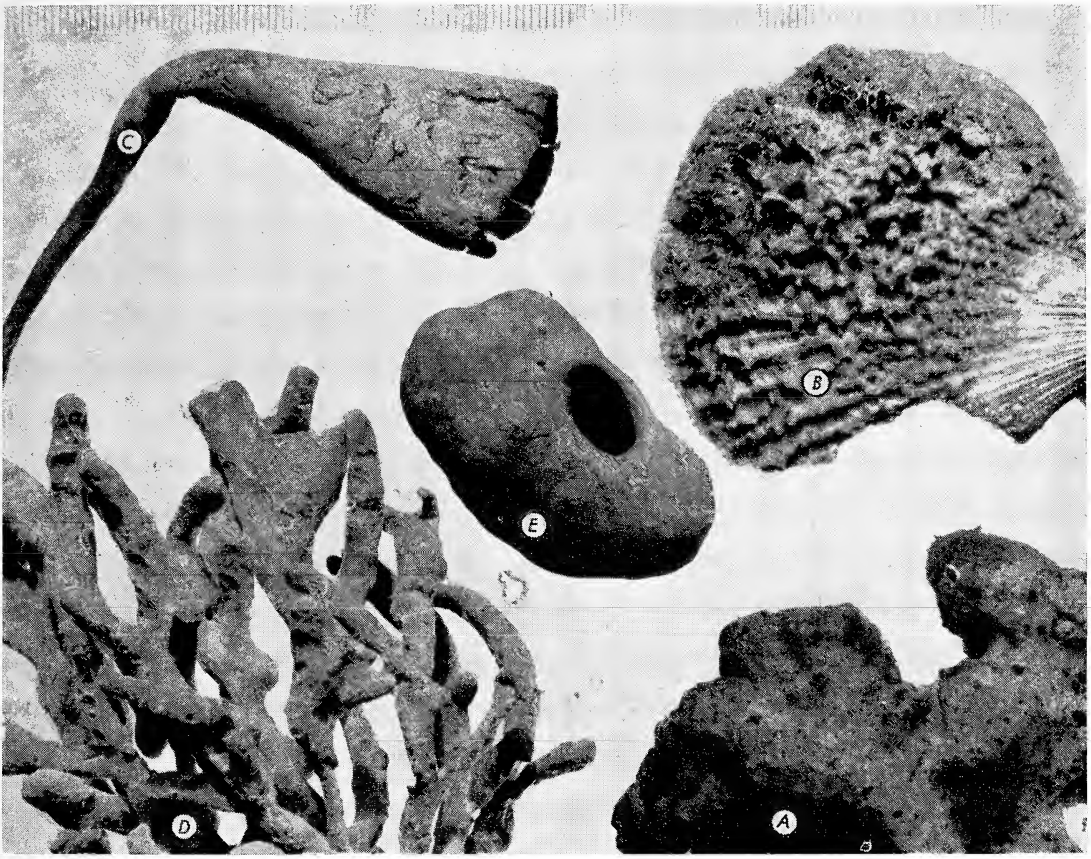

FIG. 2. *A, Sigmadocia edaphus* de Laubenfels. *B, Mycale adhaerens* (Lambe). *C, Stylissa stipitata* new species. *E, Choanites suberea* var. *lata* (Lambe).

The structure of the interior is very fibrous, the fibers themselves being plumose as seen under the miscroscope. They probably contain a small amount of spongin, but are composed chiefly of abundant rows of spicules, which are smooth styles, reaching a maximum size of about 10 × 320μ. However many are as small as 8 × 300μ and the smaller spicules occasionally show a tendency to be tylostylote. There are very numerous stout palmate anisochelas of three size ranges, 14 to 15μ, 27 to 28μ and 56 to 60μ. This largest category frequently has the spicules associated together in symmetrical groupings known as rosettes. There are also two size ranges of sigmas, the smaller having a chord length of about 20μ, and the larger of 35μ.

This sponge may be readily distinguished in the field from the other *Pecten*-covering sponge, *Ectyodoryx parasitica*, by the very fibrous structure of the interior of the *Mycale*, and the greater ease with which its ectosome may be detached from the endosome.

This species was originally described as *Esperella adhaerens* by Lambe (1893: 27) and the genus was later shown to be synonymous with *Mycale* by de Laubenfels (1936*a*: 122).

Stylissa stipitata new species
Fig. 1, *F1*, 2 C

The holotype, USNM no. 22687, was collected near False Bay of San Juan Island. It was dredged at a depth of 20 m., only 100 m. off

shore. Other specimens were taken later in the same month, July, 1931, at a depth of 45 m. at Griffin Bay.

This species is typically funnel-shaped with an elongate stem. The maximum diameter of the cone is at the distal end and at that place is 20 mm. across. The thickness of the wall is only 2 or 3 mm., and at the thinnest the stem is also only 2 or 3 mm. in diameter. The total length, or height, of the sponge is approximately 10 cm., of which 5 or 6 cm. may be described as stem, the remainder being the hollow funnel, shaped like an inverted cone.

The color in life was light drab. The consistency is spongy, very flexible, tough, and not easily torn.

The surface is moderately smooth to the naked eye, especially on the exterior of the sponge, where there is an obvious ectosomal specialization of very fine meshed reticulation. This is frequently cracked, but other than this, no oscules are evident. It is probable that the efferent openings are the abundant minute ones on the interior of the hollow funnel.

The spicules on the interior are arranged in a rather confused manner, but in general with the points towards the surface. The adjective "plumose" might be applied to the appearance in many places. There can be little doubt that this is axinellid structure. The megascleres show typical axinellid variation in size. Only smooth styles have been found; these are $2 \times 180\mu$ to $4 \times 366\mu$.

The genus *Stylissa* was established by Hallman (1914: 349) to have as genotype the sponge described as *Stylotella flabelliformis* by Hentschel (1912: 355). This East Indian species is very much like the Puget Sound one here described, except that its spicules are somewhat larger, and it is cup-shaped without any stem. Another similar sponge is that for which Gray (1867: 513) established the genus *Tragosia*, a species originally described as *Spongia infundibuliformis* by Linné (1858: 1348). It is very like the one under consideration except that it is shorter of stem and is usually broader and more cup-shaped. It is tremendously more hispid as to the surface, and its spicules include oxeas as well as styles. It is typically an European species.

Syringella amphispicula new species
Fig. 2 D

The holotype, USNM no. 22707, was dredged July 24, 1931 at a depth of 45 m. in Griffin Bay. It is a ramose sponge, with a very few anastomoses between the gnarled and misshapen branches. The latter are 3 to 10 mm. thick and about 6 cm. high, with obtuse, club-shaped ends. The color in life was ochre yellow, the consistency very tough and flexible. The surface is even but undulating, nearly lipostomous.

There is a dense axial specialization of longitudinally arranged megascleres, among which spongin may have been present, but not conspicuous. This axis often has a diameter slightly more than half that of the entire branch. In the flesh around this axial core the spicules are arranged perpendicular to the surface and at right angles to the axis. The spicules are exclusively tylostyles, many about $18 \times 670\mu$, but also much smaller. Numerous very small ones (say $2 \times 100\mu$) may be immature forms, or may constitute a separate category, but are connected to the larger type by numerous intermediates. The different sizes are mixed among each other, not localized.

This new species is unique in the genus *Syringella* for its abundance of the smaller spicules, that in it nearly make up a second size range. Many (but by no means all) of the species of this genus have a central hollow to the branches. Many have more spongin than does *amphispicula.*

Cliona celata Grant, 1826

The sponge thus identified was dredged from a depth of about 5 or 10 m. on July 3, 1931, south of Turn Island. It was found growing in a mass of broken barnacle shells, making subcircular tunnels 0.5–1.5 mm. in diameter. From them minute papilles protrude here and there a distance of about 1 mm. in life. The color in life was lemon yellow. The consistency is soft and the spicules are arranged in a rather confused fashion within the tunnels. The spicules are of one sort only; tylostyles about $10 \times 285\mu$.

This sponge was originally described by Grant (1826: 79) from Europe, but it is a well-

known cosmopolitan sponge. Its wide distribution may be due to the fact that it bores in the shells of mollusks which may transport it freely from place to place. It frequently disintegrates the shells completely in the course of time, and may do serious damage to commercial oyster beds. As an older sponge it grows up and out from its earlier boring habitat to make large yellow masses, frequently the size of a man's head. Such were not found in Puget Sound, however; only a few small boring specimens being recorded.

Choanites suberea var. *lata* (Lambe, 1892) de Laubenfels, 1936*a*

Fig. 1, *G1–2*, 2 E

The sponge thus identified is moderately common in the vicinity of Friday Harbor, frequently occurring on hermit crab shells, which may in the course of time be completely replaced by the sponge so that no trace of the calcareous material remains, except that the sponge preserved the shell-shape as a mold might.

The total mass is frequently more than 3 cm. in diameter. The color in life was gray white and the consistency was stiff, cartilaginous or cork-like. The surface is optically very smooth; pores are not in evidence, but a few oscules 2 to 4 mm. in diameter are found, usually from only one to three per sponge.

Within the sponge the spicules are densely packed, although there are distinctive gross canals 0.5 to 1.5 mm. in diameter. An even denser ectosomal region which might almost be described as a cortex extends from 0.3 to 0.7 mm. below the surface. In it practically all the spicules are placed with their points toward the surface, whereas this is frequently but not always the case in the interior of the sponge. These ectosomal spicules are perhaps slightly smaller than those of the endosome. The megascleres of this species are of one sort only, tylostyles 5 × 280 to 6 × 180μ. The microscleres are centrotylote microstrongyles 24μ long.

This species was described from European specimens as *Spongia suberea* by Montagu (1818: 100). The Puget Sound species in question was first described by Lambe (1892: 71) as *Suberites latus*. This was recorded from California by de Laubenfels (1932: 52) where it is reduced to a subspecies of *Ficulina suberea*. The genus *Ficulina* being a complete synonym of *Choanites*, however (de Laubenfels 1936*a*: 144), the genus must be designated according to the prior appellation. The principal or European variety has slightly smaller spicules, and is frequently, though not always, rosy red in color.

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Studies of the Biology of *Polychoerus carmelensis* (Turbellaria: Acoela)

KENNETH B. ARMITAGE[1]

LITTLE IS KNOWN about the biology of the Acoela. Hyman has summarized both earlier (1951) and more recent studies (1959: 731 and f.). The Acoela are of particular interest because typically they lack a gut and lack protonephridia, and frequently lack eyes. Thus they carry on a number of biological activities without having the structural modifications associated with these activities. The biology of the Acoela is of further interest because of the hypothesis of Hadzi that the Acoela are the stem group of the Eumetazoa and were derived from ciliates (de Beer, 1954; Hanson, 1958).

Polychoerus carmelensis is found in the pools of the mid-tide horizon in the vicinity of Monterey, California (Ricketts and Calvin, 1952: 49). Costello and Costello have described copulation (1938*a*) and egg laying (1939) in this species.

These studies were conducted at the Hopkins Marine Station of Stanford University, Pacific Grove, California, where the author was studying marine biology as a National Science Foundation science-faculty fellow. I wish to express my appreciation to Dr. L. R. Blinks, director of the Hopkins Marine Station, for providing facilities, and to Dr. Donald P. Abbott for introducing me to *P. carmelensis*.

REACTIONS TO SALINITY

Animals were collected from the tide pools during low tide at Point Pinos and Carmel Point. They were returned to the laboratory and placed in a flat, rectangular glass dish through which sea water (s.w.) flowed. Solutions of 25, 50, 75, 100, 125, and 150 per cent s.w. were made. The dilute solutions were made by mixing sea water from the laboratory pipes with the appropriate amount of distilled water. The concentrated solutions were made by evaporating sea water to form a 200 per cent solution and then diluting this with appropriate amounts of distilled water.

The first experiment was to determine the range of tolerance to salinity. Twenty animals were placed in each of the dilutions of s.w. They were observed for activity every hour during the first 12 hr. and then were checked every 12 hr. for 5 days. Any animals surviving after 5 days were periodically checked for another 2 weeks after which time the experiments were discontinued. Two tests were made for activity. The dishes were shaken gently; healthy animals reacted to this agitation by showing some movement in place or by locomotion. A bright light caused normal animals to locomote. Animals that did not respond to either stimulus were considered inactive until disintegration of epidermal cells was evident, at which time the animals were considered dead.

25 per cent s.w. All animals curled into a U-shaped position immediately upon being placed in the dish. After 1 hr. all animals were dead. The individuals showed a marked swelling and disintegration of the epidermal cells.

50 per cent s.w. Most animals curled into the U-shaped position within 10 min. After 1 hr., only abnormal body movements, characterized by twisting and contractions, were evident. The worms would not attach to the dish, and several extruded material, including copepods that had been engulfed, from the mouth. After 5 hr. 10 animals were transferred to normal sea water. Two hr. later half the worms were active. After 3 hr., 7 of them were active and the other 3 were uncurled. By the end of 16 hr. all animals displayed normal activity. Seven of this group were active 2 weeks later when the experiment ceased.

At 54 hr. 5 of the remaining 10 worms in 50 per cent s.w. were disintegrating and the other 5 showed some slight muscular movement when stimulated. The 5 active worms were transferred to normal s.w., but none of them survived.

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75, 100, 125 per cent s.w. All animals in these concentrations showed normal activity for 2 weeks. After 16 days, 3 animals in 125 per cent s.w. died.

150 per cent s.w. Most animals curled up shortly after being placed in the dish. One hr. later, 3 responded to the light stimulus and 7 responded upon being touched with a glass rod. The low level of activity was maintained without detectable change for the next 14 hr. By the 15th through the 24th hr. movement was limited to 4 worms who could expand and contract their anterior ends, but could not move their posterior ends. Most animals were in the U-shaped position, but some curled into an oval position. At 42 hr. a few showed feeble movements, 4 were disintegrating, and the remainder were in the U-shaped position. Twenty-four hr. later all of the animals except 3 were disintegrating and only 1 was capable of any movement.

The second experiment was set up to determine if the worms are capable of acclimating to levels of salinity. The experiment was not designed to determine the range of acclimation to salinity, but to demonstrate that acclimation was possible. Fifty animals were placed in 75 per cent s.w. 96 hr. prior to testing. Survival times in 30, 40, 50, 60, and 70 per cent s.w. were determined for worms acclimated to 75 per cent s.w. and 100 per cent s.w. Ten animals were placed in each solution.

30 per cent s.w. All worms were immobile. In 2 hr., 7 of the group acclimated to 100 per cent s.w. and 3 acclimated to 75 per cent s.w. were sloughing epidermal cells. At 8 hr., all of both groups were disintegrating.

40 per cent s.w. All animals of both groups were immobile and failed to respond to normal stimuli. However, at 8 hr. 7 of the group acclimated to 75 per cent s.w. responded to a light stimulus from a no. 2 photoflood. Six of these were still active at 12 hr. and 5 showed feeble movements at 24 hr. None of the group acclimated to 100 per cent s.w. showed any response at any time.

50, 60, 70 per cent s.w. The number of animals surviving in each of these three concentrations is plotted against time in Figure 1. The curves for the animals tested in 50 per cent s.w.

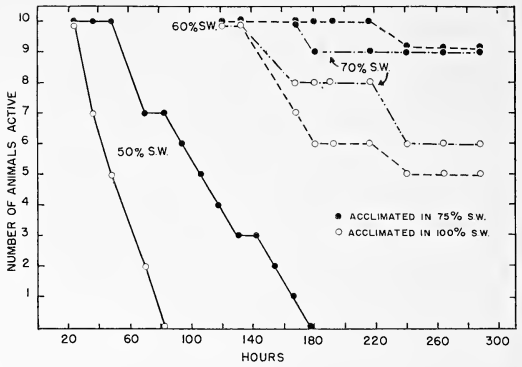

FIG. 1. Number of active animals plotted against time for *P. carmelensis* acclimated to 75 per cent s.w. and 100 per cent s.w. and tested in 50, 60, and 70 per cent s.w.

indicate that acclimation has taken place and has acted to increase survival time in the acclimated animals. The curve also indicates that the difference in survival time between the two acclimated groups increases with increasing time in the test environment. The curves also illustrate the variability in tolerance to salinity among individuals. This is particularly evident in the curves for the animals tested in 60 per cent s.w. and in 70 per cent s.w. After the least tolerant individuals of the worms acclimated to 100 per cent s.w. died, all the groups reached an equilibrium with essentially all the remaining animals surviving.

DIURNAL RHYTHM

The only known case of a persistent rhythm in the phylum Platyhelminthes has been reported for the acoel *Convoluta roscoffensis* (Harker, 1958). The worm comes to the surface of the sand at low tide and disappears into the sand when the tide returns. The rhythmic behavior is maintained in the laboratory for about 1 week in vessels of still water and is independent of day or night. *P. carmelensis* is found on the upper surfaces of algae or gravel during low tide and disappears into the gravel as the tide returns. The similarity between the two species makes desirable a study to determine if a diurnal or tidal rhythm occurs in *P. carmelensis*.

About 150 worms were collected near Pt. Pinos and brought into the laboratory. Ten animals along with a few pieces of rock were

placed in each of 10 plastic bowls. Two additional bowls were filled with gravel and 10 worms were placed in each. All the bowls were placed in an aquarium with the sides and top covered to keep out all light. In addition, the room was also darkened. Sea water from the laboratory system was circulated around the plastic bowls as a temperature control. The number of animals visible in each bowl was determined approximately every 2 hr. from 0800 until 2200 hr. for 2 days and spot-checked for 2 more days. The counts were made under a dim light.

During the first day there was a gradual increase in the number of worms that were visible. This leveled off by the morning of the 2nd day. The number of animals visible at the time of each count for the 2nd day is given in Table 1. There is no relationship between the number of animals visible and the time of day or the condition of the tide. Nor did the subsequent spot checks indicate any relationship. From this it is concluded that *P. carmelensis* does not show any diurnal or tidal rhythm of activity.

Observations in the field indicated that *P. carmelensis* came to the surface during low tide when the water was quiescent in the tide pools and when the light was relatively dim. If one waded through a pool in which the animals were located, one could observe the animals begin a downward movement. A similar downward movement was observed when the first waves of the incoming tide reached the pool. These observations indicated that water agitation was the stimulus for movement downward.

The following laboratory experiment tested the field observation. The data in Table 1 show that there was not much variation in the number of animals visible in the plastic bowls in the darkened aquarium. The number observed was particularly stable in the plastic bowls with gravel. Two bowls with rocks and two bowls with gravel were lighted sufficiently so that the animals could be counted. There was no reaction to the light in any of the dishes. Each of the bowls with gravel had 10 animals visible. One bowl was shaken gently; all the animals immediately became active and began crawling down into the gravel. After 3 min., only 2 worms were visible and both of them were crawling. All 10 animals remained visible in the control dish which was not shaken and only 1 animal was active. There were 5 worms on top of a rock in a third bowl. When this bowl was agitated, all the worms became active; 4 of them crawled under the rock within 2 min. The other animals in the bowl also became active, but could not move down as they were on the bottom of the dish. There was no activity in the fourth bowl, which also had a rock and served as an unshaken control to compare with the third bowl. From these experiments and from the field observations, it was concluded that *P. carmelensis* is negatively geotaxic in quiet water and positively geotaxic in agitated water.

TABLE 1

TOTAL NUMBER OF ANIMALS VISIBLE IN PLASTIC BOWLS WITH ROCK AND WITH GRAVEL
(Ten animals were placed in each bowl)

TIME OF OBSERVATION	NO. VISIBLE IN 8 BOWLS WITH ROCK	NO. VISIBLE IN 2 BOWLS WITH GRAVEL	TIME OF TIDE
0800	56	19	
			0810 low
1000	64	20	
1200	62	20	
1400	48	19	
			1444 high
1500	54	19	
1600	62	20	
2000	51	20	
			2105 low
2200	53	17	

During low tides when bright sunlight was present, *Polychoerus* was found under rocks and gravel, indicating that the genus might be positively geotaxic under bright light.

Twenty-one animals were distributed in six 25 × 75 mm. plastic vials so that there were at least 3 worms in each vial. The worms were allowed to come to rest after being added to the vials. The number of worms on the side of the vials was determined. Then the worms were stimulated for 3 min. with various intensities of light. All activity was recorded. The worms were kept in total darkness for 1 hr. between subsequent tests. The same worms were used throughout. The results are summarized in Table 2. Low light intensities had essentially no effect on the animals. Higher light intensities resulted in an increase in over-all activity with all animals becoming active at the highest intensity of light. Animals never crawled upward. There was an increasing percentage of animals on the sides of the vials that crawled downward with the increase in light. This experiment indicates that *P. carmelensis* becomes more active with increasing light intensity, and where directed movement is possible the animal crawls away from the source of light. Thus the absence of animals on the upper surface of rock and gravel during low tide and bright sunlight can be attributed to the reaction to light demonstrated above.

REACTIONS TO LIGHT

In the previous section some of the reactions of *P. carmelensis* to light were described. That experiment was designed to explain part of the upward and downward movement of the worms in the intertidal substrate in the absence of a diurnal rhythm. The reactions to light led to some further exploration of the behavior of the worms in relation to light.

The increase in the number of animals showing locomotion on the bottom of the vials at higher intensities of light (Table 2) indicated a photokinetic response. Photokinesis is usually defined as a change in the rate of undirected locomotion resulting from a change in the intensity of light. The photokinetic response in *P. carmelensis* was measured in two experiments.

The first experiment was designed to measure the rate of crawling under varied intensities of light. Two narrow strips of plastic were fastened 6 mm. apart in the bottom of a petri dish with a diameter of 14 cm. The plastic strips and the bottom of the dish were covered with black friction tape. A 5 cm. course was marked off between the plastic strips. The course was illuminated from one end. A worm was dropped into the dish at one end of the course with the light turned on, and the time that elapsed until the worm reached the end of the course was determined. The behavior of the worms was highly erratic. Some of them spent considerable time in turning the head from side to side, others ceased crawling before reaching the end of the course, and some crawled directly down the course. All of the worms were photonegative at the intensities used. Because of the variability in behavior, the experiment was discontinued after a small series of determinations were made. The rates of crawling for worms that crawled directly down the course illuminated by means of 5 ft. c. and 37 ft. c. were analysed by means of an analysis of variance and the between groups variance was statistically significant. The mean rate of travel was 0.86 mm/sec at 5 ft. c. and 1.34 mm/sec at 37 ft. c. The rate of crawling increased about 55 per cent when the light intensity was increased about 640 per cent. Similar slight increases in the rate of crawling with large increases in the intensity of light were found for *Dugesia gonocephala* and *Plagiostomum* sp. (Carthy, 1958: 37).

A second experiment attempted to measure photokinesis by determining the amount of activity initiated in a population of quiescent worms illuminated at various intensities of light. Five worms were placed in each of five petri dishes filled with sea water. After 1 hr., the worms were illuminated dorsally at various light intensities for 3 min. The time in seconds for a worm to respond was determined, as well as the nature of the response. Responses were of three types, (1) head raising; (2) body movement in which the animal might swing the anterior end side to side several times or show other changes in body form, but remaining essentially in the same location in the dish; (3) locomotion, in which the animal actively crawled about the dish. An activity index was determined

TABLE 2

REACTIONS OF *P. carmelensis* TO LIGHT OF VARIOUS INTENSITIES
(A total of 21 animals in 6 vials were tested for 3 min. at each intensity)

LIGHT INTENSITY ft. c.	NO. ON SIDES	NO. MOVING DOWN	PER CENT MOVING DOWN	HEAD MOVEMENT AT SURFACE	LOCOMOTION ON BOTTOM
1.7	15			1	
10.0	9			1	
37.0	8			3	2
130.0	11	4	36	3	5
225	8	7	87	1	12
400	5	5	100		16

by assigning an arbitrary value of 5, 10, and 20, respectively, to each of the above responses and dividing the sum of the values for individual worms by the sum of the number of seconds that elapsed until the animal responded or until 180 sec. elapsed. Animals that did not respond were included. This may be illustrated in the following equation:

$$\text{Activity index} = \frac{\text{sum of arbitrary values of response for all worms}}{\text{sum of number of sec. until response or until elapse of 180 sec. for all worms}}$$

The activity index will be higher if the number of animals responding to the stimulus increases or if the nature of the response is of a higher level or if both of these occur. The results are presented in Figure 2. Activity appears to be linearly related to light intensity over the ranges of light intensity studied. It is difficult to know if this relationship is a real one, for it might be an artifact of the method used to determine activity. However, the raw data indicate such a linear relationship, so that this relationship seems reasonably accurate. It probably does not exist at higher intensities, for once an animal has responded fully it can no longer respond to an increased stimulus.

On contrasting backgrounds, planarians come to rest on the darker ground (Ullyott, 1936). This reaction was tested in *P. carmelensis* in the following manner. Half the bottom, the sides, and the upper edge of the sides of a 4½-in. petri dish were painted black and the other half of the bottom was painted white. The dish was half-filled with sea water and placed in a metal trough through which sea water circulated to maintain a relatively constant temperature and illuminated from above by 15 ft. c. of light. Ten (in some experiments, 20) animals were added to the petri dish as close to the center as possible. The animals were allowed 1 hr. to come to rest, after which the animals on each background were counted. The dish was rotated 90° between trials so that if the animals were reacting to light being reflected from the wall of the room or from the sides of the dish, such a directional orientation could be detected. The position of rest of each animal for each trial was plotted on a drawing of a petri dish. There was no evidence of directional orientation in any of the experiments. Forty different individuals were used in the first set of experiments. All animals were kept in the dark between trials. Any animal that crawled up on the side of the dish was considered to be on a black background. The experiments extended over 5 days. Of 40 animals tested, 33 came to rest on the white background and 7 came to rest on the black background. The marked orientation to the white background (chi square = 16.8, $p < 0.001$) was unexpected in view of the results with planarians. The testing was repeated four times using the same animals. The results were similar in all cases. Since all of the animals came from an area of broken shell, most of which was white, it was postulated that the animals were acclimated to the white background. If this hypothesis were correct, then it should be possible to acclimate the worms to a black back-

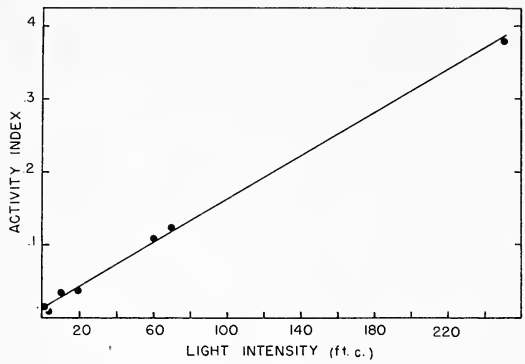

FIG. 2. The activity index of a population of *P. carmelensis* plotted against light intensity. Curve fitted by eye.

ground. Twenty animals were kept under constant light in a black plastic bowl for 96 hr. The animals were tested at 24, 72, and 96 hr. At 24 hr., 12 animals oriented to white and 8 to black, showing no significant difference (chi square $= .8$, $p < 0.5$), 72 hours, 8 oriented to white and 12 to black, again showing no significant difference. At 96 hr., 5 oriented to white and 15 to black, now showing a significant difference (chi square $= 5.0$, $p < 0.05$). The animals were tested again 2 days later. During the two days, they were kept on the black background but received light only from 0800 to 1800 hr. Several tests were run, with the animals being kept in darkness between tests. In the first test, 5 animals stopped on the white background and 15 on the black background. The marked orientation to the black background was significant (chi square $= 5.0$, $p < 0.05$). However, when the test was repeated using the same animals, two of the tests gave essentially the same results, but the third showed no difference in background selection.

A second series of tests for background choice was made with newly collected worms from Carmel Point. Forty worms were placed in black dishes and 40 were placed in white dishes. The worms were kept under constant light and tested after 96 hr. The testing extended over 2 days and the animals were kept in darkness during the period of testing. The animals were tested under 35 ft. c. of light. The animals kept on a white background went to the white side of the dish 27 times and to the black side 11 times. The selection of the white background is highly significant (chi square $= 6.7$, $p =$ c. 0.01). The animals kept on the black background went to the white side of the dish 9 times and to the black side 29 times. The selection of the black background is highly significant (chi square $=$ 10.5, $p < 0.01$). Each of these tests was repeated once using the same animals. Results were essentially identical.

The animals were kept in their respective dishes and given 48 hr. of constant light. They were then placed in the dark and subsequently tested under 70 ft. c. of light.

The animals kept on a white background went to the white side of the dish 21 times and to the black side 16 times. There is no indication that background selection occurred (chi square $= 0.66$, $p < 0.5$). However, the animals kept on a black background went to the black side of the dish 33 times and to the white side 7 times. Selection of the black background was significant (chi square $= 16.0$, $p < 0.001$). Each of these tests was repeated twice using the same animals. The worms acclimated to the black background showed about the same pattern, but with lowered chi-square values. The animals acclimated to the white background showed almost complete randomness in selection of background (chi square $= 0.01$).

These is no ready explanation for the shift in background selection by the worms acclimated to the white background. The experiments concerning photokinesis demonstrated that the worms had a differential sensitivity to light, some reacting to a weak stimulus, others to a strong stimulus. Because of the variation in sensitivity to light, it seems reasonable to postulate that under the increased light intensity, photokinesis was stimulated more in the light-sensitive animals. These sensitive animals then oriented to the black background to reduce the amount of stimulation. The less sensitive animals continued to orient to the white background to which they were acclimated. That there is a threshold of sensitivity to light whereby the reaction to light stimulation is reversed is indirectly indicated. Costello and Costello (1938*b*) reported that *P. carmelensis* may "...be positively phototropic to moderate light intensities"; the positive phototropism was

evidenced by the gathering of the worms on the lighted side of the aquarium in which they were kept. Taxic reactions were not studied as such in this series of experiments, but the experiments on diurnal rhythm demonstrated that the animals were negatively phototaxic at high light intensities and showed no response at low intensities. Thus the possibility of a differential response to low and high light intensities exists, as has been found for other animals (Clarke, 1930; Baylor and Smith, 1957). Clarke (1932) found that a change of illumination must rise above a certain threshold to be effective in causing a reversal of phototropic signs in *Daphnia*.

It was mentioned previously that worms acclimated to a black background showed a lesser degree of choice of the black background when the tests were repeated. Since the animals were kept in darkness except while being tested, it seemed possible that some of the worms were losing their acclimated condition and perhaps were moving in a more random manner. Therefore, both the animals acclimated to a white background and the animals acclimated to a black background were illuminated with 70 ft. c. for 12 hr., placed in darkness for 12 hr., and then tested. Thirty of the animals acclimated to the black background came to rest on the black background while 8 selected the white background. The orientation to the black background was highly significant (chi square $= 12.6$, $p < 0.001$). Nineteen of the animals acclimated to the white background came to rest on the white background and 19 selected the black background. Thus it was not possible to condition the animals to select the white background under 70 ft. c. of light under the conditions of the experiment. However, the animals acclimated to the black background responded almost to the same degree as in the original test. This experiment suggests that failure to maintain an orientation to a white background at 70 ft. c. is a result of animals more sensitive to light changing their orientation from the white background to the black background.

FEEDING BEHAVIOR

Five *P. carmelensis* were placed in a Syracuse watch glass with a dozen copepods, *Tigriopus californicus*. One of the copepods came to rest near the left anterior end of a *Polychoerus* which had stopped crawling. The anterior end of the worm was raised and with a sudden whiplike movement it was brought down over the *Tigriopus*. The worm assumed a cup-shaped position over the copepod. The copepod was quickly engulfed and its movements inside the body of the worm could be observed. These movements continued for 10 min. The capture of the crustacean by *Polychoerus* was similar to the manner of prey capture by the acoel *Convoluta paradoxa* (Jennings, 1957). Dead *Tigriopus* were not ingested.

CONCLUSIONS

1. *P. carmelensis* can tolerate salinity conditions ranging from 75 to 125 per cent s.w. indefinitely. Worms were quickly inactivated at concentrations of sea water above and below these values. Animals kept in 50 per cent s.w. for 5 hr. and transferred to 100 per cent s.w. recovered normal activity by 16 hr. after transfer.

2. *P. carmelensis* was acclimated to 75 per cent s.w. and survival time was increased at the range of salinities tested over controls acclimated to 100 per cent s.w.

3. There was no evidence of a diurnal or tidal rhythm of activity. Worms tended to be negatively geotaxic in quiet water at low light intensities and positively geotaxic in agitated water or at high light intensities.

4. Photokinesis, measured as the amount of activity in a population of worms, was linearly related to light intensity over the range of light intensities used. Only slight differences were found in the rate of crawling of worms over a measured course under highly different intensities of light.

5. At 15 ft. c. light intensity, worms collected from tide pools with white shell and rock chose the white background when placed in a petri dish with half the bottom painted white and the other half black. Worms were acclimated for 96 hr. in dishes painted black and in dishes painted white. The black-acclimated worms chose the black background and the white-acclimated worms chose the white background when tested in the petri dish with contrasting backgrounds of black and white. The reaction was

highly significant at 15 ft. c. and 30 ft. c. However, at 70 ft. c., the worms acclimated to a white background showed no preference when tested on contrasting backgrounds. The worms acclimated to the black background continued to orient to the black background when tested on contrasting backgrounds. It was postulated that the change in response at 70 ft. c. of animals acclimated to the white background was a result of crossing a threshold of light sensitivity so that the more sensitive animals tended to orient to the black background while the less sensitive animals tended to orient to the white background.

6. The capture of a copepod prey is described.

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Preliminary Tests of the Toxin Extracted from California Sea Hares of the Genus *Aplysia*[1]

LINDSAY R. WINKLER[2]

DURING A STUDY of the biology of California sea hares (Winkler, 1957), the large amounts of absorbed but unused substances from the sea hare's diet which are to be found in the digestive gland were noted. On the assumption that if there are toxic sea weeds in the diet of the sea hare these toxins might possibly be present in the digestive gland, samples of the exudate from frozen digestive glands on hand were removed with a small pipette and were placed in test tubes. The test tubes were then placed in a boiling water bath for 10 min. After being centrifuged, milliliter aliquots were injected intraperitoneally into 20-gm. C57 black mice. The digestive glands of *Helix aspersa* O. F. Muller were similarly treated as controls. The animals injected with the experimental extract showed almost immediate respiratory symptoms followed by an excitement stage and death in 4 to 6 min. Since neither the controls nor ashed samples reconstituted and injected produced these effects, further study seemed desirable. Certain general aspects of the resulting study are reported here.

It may or may not be significant that Latin and Medieval writers, beginning with Pliny (*ca.* A.D. 60) considered the sea hare to be very poisonous and claimed its use in poisonings during the days of Imperial Rome. An excellent summary of the beliefs and superstitions pertaining to the sea hare is given by Johnston (1850).

MATERIALS AND METHODS

Collections in March, April, and May were made at Doheney Beach near Dana Point, California. Later collections were made from May through August at Lunada Bay, Palos Verdes, Los Angeles County, California. The former were small specimens between 4 and 6 in., the latter were large breeding specimens measuring to 1 ft. in length. Animals were collected at low tides, packed in wet *Pelvetia fastigiata*, and transported back to the laboratory where they were either immediately dissected or were refrigerated until the next day. In either case, the animals were alive when dissected and no difference in the toxic effect was noted between those dissected immediately and those stored overnight.

The digestive glands were dissected out by making a longitudinal, midpedal cut with scissors in the ventral surface of the foot from the tail to the lip area. The animal was then turned inside out. The digestive gland was removed, including the part of the intestine embedded in the gland and the ovotestis, which is an integral part of the digestive gland complex. The percentage weight of the digestive gland complex to the weight of the intact animals was determined in a certain number of cases. Samples of the crop and/or intestinal contents were preserved in alcohol and studied where it seemed desirable in a rough attempt to ascertain if the diet was responsible for the toxicity. Specimens of *Aplysia vaccaria* Winkler were also collected and dissected for extraction. The digestive glands were stored in glass containers in a deep-freeze and were not thawed until ready for use.

It early became apparent that a more refined method of extraction than the water methods used initially was necessary because of the large amounts of pigments, salts, and apolar materials present in the gland. After much trial and error the following method proved the most satisfactory for large-scale crude extract preparation. Thawed digestive gland (130–150 gm.) is placed in a Waring Blendor. When the gland is thoroughly liquified, 400 ml. of acetone is

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slowly added, and after a few minutes the entire mixture is quickly filtered. The residue is then rinsed with an additional 100 ml. of acetone. The acetone extract, containing the tissue "water" from the digestive gland is then placed in the flask of a rotary evaporator, partial vacuum being supplied by an aspirator. As the percentage of acetone is reduced by evaporation, the apolar fraction is thrown out of solution and deposited on the flask wall. When the remaining "water" has been evaporated to about 50 cc., it is placed in a refrigerator overnight, after which it is refiltered and becomes what is referred to as the crude extract.

The routine bio-assay procedure for indicating relative strength of extracts in the toxic principle consists of injecting 1 ml. of an extract intraperitoneally into mice of similar weight and observing the death time to the last heartbeat audible with a stethoscope. The death time serves as a rough indication of the relative toxicity.

Initial LD_{50} values were obtained by conventional methods using three groups of mice to establish three points on a graph plotting percentage mortality against dose given. The LD_{50} values were then read from the graph. Subsequent LD_{50} approximations and those for the chick were determined using a minimum number of animals by the "up and down" method proposed by Dixon (1959). Since the LD_{1-99} range is very narrow, this latter method gave adequate results for the present purposes.

EXPERIMENTAL RESULTS

The average percentage weight of the digestive gland/ovotestis complex of *A. californica* based on 15 specimens was 10.8 per cent, and the range was from 8.4 to 14.0 per cent. Varying amounts of sand were found in the intestines of this species, which influenced the accuracy of the weights. The accuracy was higher for *A. vaccaria*, however, since no sand was found in the intestines. The average percentage based on 5 specimens of the latter species was 19.4 per cent, ranging from 18.0 to 20.3 per cent.

The diet varied between the two collecting sites. At Doheney Beach the diet followed the predominant flora consisting of several coralline algae and *Hypnea californica*. A considerably wider variety of seaweeds was noted in the Lunada Bay collections. The Lunada Bay sea hares appeared to be more toxic but this may have been the result of more maturity or merely a reflection of variation in the extraction efficiency. No correlation is possible at the present state of the research.

Aplysia vaccaria, a sea hare rather distantly related within the genus, possesses a similar toxin in its digestive gland.

The LD_{50} was determined for 23-gm. mice and is expressed in grams of digestive gland tissue. Two different batches of raw material were used to obtain two somewhat removed values. Each batch represents the material obtained from 5 to 12 sea hares, depending on the animals' size. One batch collected May 4, 1959, had an LD_{50} value of 0.65 gm. tissue for a 23-gm. mouse (0.028 gm/gm body weight). Another collected at the same location July 28, 1959, had a value of 0.8 gm. per 23-gm. mouse (0.036 gm/gm weight). However, the difference in the two values may represent only differences in extraction efficiency rather than true variation in toxin concentration.

The LD_{50} for 3-day-old baby chicks was found to be only slightly less than 25 per cent more than that for mice.

When mice are injected intraperitoneally with the crude toxin of somewhat more than the LD_{50} dosage, there is an almost instantaneous hyperventilation. Ears are drooped and the mouse usually sticks his nose in a corner of the cage and salivates profusely. After a varying time in which hyperventilation is evident, the mouse starts scurrying about the cage, usually leaving a trail of urine. Perhaps it then returns to its corner or begins to demonstrate occasional muscular twitching which may turn into uncontrolled attempts at movement suggesting a convulsion. This uncontrolled movement may develop in waves and once begun is always terminal. Ataxia and inability to right itself usually develop before or during these uncontrolled movements. The animal passes into a completely relaxed state. The heart continues for some time at a reduced pace, gradually becoming weaker until it can no longer be heard with a stethoscope. The toxin also killed mice

when given by stomach tube at approximately 12 times the intraperitoneal LD_{50} dose.

Helix aspersa O. F. Muller withstood doses of the toxin sufficient to kill several mice with only temporary effects. However, the purple shore crab quickly went into a relaxed state when small quantities were injected at the podial interstices. Since they were presumed dead, they were not observed further.

When frogs are injected with the LD_{50} dose/gm weight for mice, the dorsal appendages become weakened and paralyzed in approximately 5 min. This is followed quickly by relaxation (Fig. 1), complete except for the anterior limbs, which become spastic. The rectus abdominis is also tensed. The muscles controlling the eyes are the last to become paralyzed. A complete deathlike stupor follows, lasting about 15 hr. The first reaction to reappear is the movement of the nictitating membrane and retraction of the eyes. Soon thereafter, when teased in the eye region, an isolated leg twitch may occur, usually in the thigh region. As time progresses, teasing produces an initial kick followed by complete immotility for a time. In 3 to 5 hr. more the frogs recover completely.

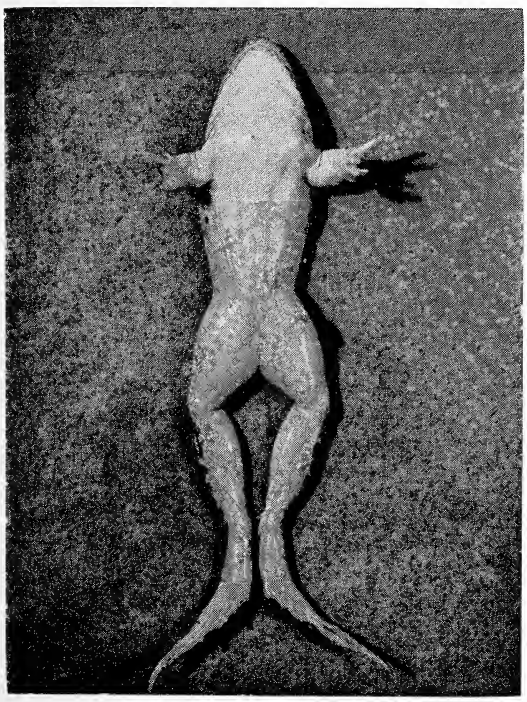

FIG. 1. The reaction of the frog to the toxin of *A. californica*. Note the tensed abdominal muscles and forelegs.

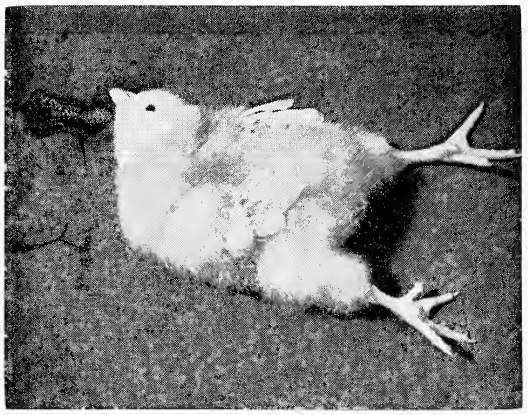

FIG. 2. The reaction of the chick to the toxin of *A. californica*. The toxin was injected subcutaneously over the breast.

Three-day-old baby chicks were injected with lethal doses to observe symptoms. Immediate hyperventilation occurred, followed in order by ataxia, relaxation of the wings, and a stretching of the legs (Fig. 2), which were relaxed only terminally. Hypersalivation and difficulty in swallowing were apparent. Respiratory arrest preceded a final convulsive effort before complete cessation of movement.

Rats and guinea pigs show symptoms quite similar to those of the mouse. Kittens, on the other hand, passed through a short but violent wretching and vomiting stage. Hyperventilation, relaxation of the vocal cords and nictitating membrane, and dilation of the pupils followed. Relaxation of forepaws and neck muscles preceded respiratory distress, violent tail wagging, terminal respiratory arrest, and relaxation of the bladder sphincter muscles.

DISCUSSION AND CONCLUSIONS

The common denominator of the lethal symptoms observed seems to be respiratory paralysis with no other noticeable lethal effects. Frogs, though able to survive doses paralyzing their lung respiration for 15 hr. or more, succumbed sporadically to a wide range of much larger doses. This may indicate other less dominant

lethal effects masked by the respiratory arrest. However, respiratory arrest seems to be the limiting factor in birds and mammals, though a suggestion of other contributing effects is noted in the chick. Studies on isolated preparations are now in progress and will be reported later.

At the present stage of the study it is impossible to postulate the function, if any, or the ultimate source of the toxin. The absence of any method for the animal to inject the toxin along with the high dosages required to be effective orally would seem to preclude any defensive use. However, both concentration of the toxin from the seaweed diet or an endocrine function may be considered as possibilities.

SUMMARY

1. The digestive gland of *Aplysia californica* and *A. vaccaria* contain a water- and acetone-soluble toxin.

2. Crude extracts produced muscular weakness and death by respiratory arrest when injected intraperitoneally into various laboratory animals or given orally at about 12 times the IP dose.

3. Frogs survived a respiratory arrest and complete paralysis for 15 hr. When extracts are given in much larger doses, death ensues from causes not yet determined.

4. From observation of these symptoms, it is suggested that the primary lethal effect in mammals and birds is respiratory arrest, though other less dominant lethal effects seem to operate in the frog.

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A Contribution to the Biology of the Convict Surgeonfish of the Hawaiian Islands, *Acanthurus triostegus sandvicensis*[1]

JOHN E. RANDALL[2]

THE SURGEONFISHES (family Acanthuridae), which are distinctive chiefly in their possession of a knifelike spine or spines at the base of the tail, are one of the dominant groups of tropical inshore marine fishes. Over much of their vast range, including Hawaii, where they are especially prominent on the reefs, they are important components of subsistence fisheries. Little is known of their biology, however. There are only scattered references to the herbivorous food habits of the group and general remarks on the habitat of certain species.

An analysis of the generic classification of the family and taxonomic revisions of some of the genera have been published (Randall, 1955 *a*, *c*, *d*; 1956*b*). The largest genus, *Acanthurus*, contains 32 species, 4 of which occur in the Atlantic, and the rest in the Indo-Pacific. The present paper constitutes a report of a study made during 1952–55 upon the life history and the ecology of one Hawaiian subspecies of this genus, *A. triostegus sandvicensis,* the convict tang or convict surgeonfish. In Hawaii and elsewhere in Polynesia this surgeonfish is known as the manini, and hereafter it will usually be referred to by that name.

The manini is the most abundant species of surgeonfish in the Hawaiian Islands and commercially the most important. Judging from its prevalence in museum collections, it is also common elsewhere in the Indo-Pacific region. Jordan and Seale (1906: 354) wrote, "This species is the most abundant of the genus about Samoa, swarming everywhere on the reefs." The young reside in tidepools, and are therefore more accessible for observation and experimentation than the young of other acanthurids in Hawaii which are usually found in deeper water. The species has the widest distribution of all of the surgeonfishes—East Africa to the Gulf of California (a single record from West Africa by Fowler, 1936, should be confirmed). Thus interest in its biology may be greater than that of a localized species.

A. triostegus (Fig. 1) has been described under 10 different scientific names and placed in six different genera. Nomenclatural considerations and description of the species and variants, with special reference to fin-ray counts and coloration, have been dealt with previously (Randall, 1956*b*).

ACKNOWLEDGMENTS

This research was done in partial fulfillment of the doctoral thesis requirement at the University of Hawaii. The author wishes to express his sincere thanks to the members of his doctoral committee, headed by William A. Gosline of the Department of Zoology, for their guidance.

Personnel of the Hawaii Division of Fish and Game, then under the direction of Vernon E. Brock, helped materially in the tagging program of the manini. The tagging was financed by the Federal Aid in Fish Restoration Program. The larval fish collection of the Pacific Oceanic Fishery Investigations (POFI) of the United States Fish and Wildlife Service was made freely available.

H. W. Manter and Leland S. Olsen of the University of Nebraska, Paul Illg of the University of Washington, Cadet Hand of the University of California, J. Percy Moore of the University of Pennsylvania, and Alan Lewis of the University of Hawaii, assisted in the identification of parasites.

Most of the photographs were taken by Charles E. Cutress of the U. S. National Museum.

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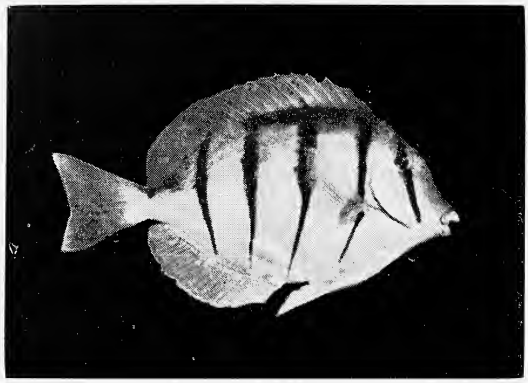

FIG. 1. Adult manini, *Acanthurus triostegus sandvicensis*, from Hawaii. Standard length, 154 mm.

HABITAT

In the Hawaiian Islands the manini occupies a diversity of habitats. It occurs in bays, harbors, and exposed reef areas. It abounds in tide pools and shallow water, yet is known at depths of at least 100 ft. Areas of very turbid and brackish water are usually avoided, but a few manini have been collected even in these regions.

Like most reef fishes, the manini avoids extensive stretches of sand or mud bottom, preferring instead the nearness of holes or crevices in the reef for shelter and solid bottom for the growth of its algal food.

The manini appears to be more restricted in habitat in the Gilbert and Marshall islands, possibly because of the sharper definition of the ecological zones of these atolls. It occurs in these atolls both in the lagoon and outer reef areas; however it seems to be confined to relatively shallow water. On the outer reef the fish were seen only on the reef flat, the young in great abundance in the shallower sections and the adults on the seaward portions (for data from a reef-flat transect in the Gilbert Islands, see Randall, 1955*b*: 181). The species was only rarely observed in the turbulent surge channel zone and was never seen on the coralliferous terrace (benched area of living coral offshore from the reef flat).

As in the Gilberts and Marshalls, the presence of heavy coralline areas in the Hawaiian Islands seems to limit the manini. This is apparent from the underwater transect work of Brock (1954). Areas like the northern part of Kealakekua Bay, Hawaii, where the coral growth is extremely rich for the Hawaiian region, are almost devoid of manini. Since this species is herbivorous, its diminution in coral areas may be associated with the small amount of substratum available for the growth of algae. Surprisingly, other surgeonfishes such as *Acanthurus leucopareius*, *A. achilles*, *Zebrasoma flavescens*, and *Ctenochaetus strigosus*, usually less abundant than manini, are the most common fishes in this part of the bay. With the exception of *C. strigosus* which is a detritus feeder (Randall, 1955*d*), these species are more inclined to crop close to the substratum than the manini, judging from the greater amount of inorganic debris in their stomach contents, and they may therefore be superior competitors under such conditions.

The eggs and larvae of the manini are pelagic. This has been ascertained by a study of development following artificial fertilization of the eggs, by the capture of larvae in plankton nets, and by the taking of the late postlarval or acronurus stage at night lights offshore.

A total of 11 acanthurid larvae (at least 3 of which are manini), 4.2–8.7 mm. in total length, were found in the plankton collections from Hawaiian waters of Cruises 4 (May 1950) and 6 (August 1950) of the "Hugh M. Smith," a POFI research vessel. These fish were taken at eight stations ranging from about 10 to 140 mi. from the nearest island (for more exact locations, see King and Hida, 1954: fig. 1, stations 1A, 10, 13, 15, 17, and 23 of Cruise 4 and stations 7 and 14 of Cruise 6). They were captured in horizontal tows made with fine-meshed plankton nets (1 m.) which sampled three different levels simultaneously. For both cruises combined, a total of 58 hauls were made at the surface, 24 at a depth of 50 m., and 112 at depths from 100 to 300 m. Six of the larvae were taken at the surface, 5 at 50 m., and none at greater depths. The failure to find more larvae in these collections is probably due to the distance from land of most of the stations. Only 6 of the 29 stations of each cruise were within 25 mi. of any of the Hawaiian Islands and only 1 within 10 mi. The absence of larval *Acanthurus* longer than 8.7 mm. in the collections is probably due to the ability of larger larvae to elude

the plankton net. The lack of specimens shorter than 4.2 mm. may be the result of a paucity of small larvae so far offshore.

That acanthurid larvae, in general, are more abundant close to land has been shown by Reintjes and King (1953). These authors found a total of 1,067 acanthurid larvae in the stomach of 184 of 1,097 yellowfin tuna (*Thunnus macropterus*) sampled from the region of the Line and Phoenix islands. They stated that the acanthurids were common in the stomachs of nearshore yellowfin, along with balistids and carangids. Representatives of the Bramidae, Exocoetidae, and Gempylidae predominated in the stomachs of offshore yellowfin.

King kindly allowed me to examine the stomach content work sheets in order to compare the occurrence of larval acanthurids in the stomachs of tuna caught at the surface by pole-and-line fishing and by trolling with those caught at depths of about 30 to 160 mi. by long-lining. The comparison revealed more acanthurid larvae in the stomachs of surface-caught fish.

The acronurus larval form of the manini, averaging about 26 mm. in standard length in the Hawaiian Islands, leaves the pelagic realm and enters very shallow water, often tide pools, to transform to the juvenile stage. Although juveniles tend to remain in shallow water, there is a progressive movement with increasing size to somewhat deeper water. Adults are not entirely absent from tide pools, however. Several were seen in pools 1–3 ft. deep cut off from the open sea at low tide on Moku Manu and Manana (Rabbit) islands. Also, at night on Oahu, manini as large as 70 mm. were occasionally found in high tide pools.

TOLERANCE TO TEMPERATURE AND SALINITY

In order to determine if the manini is capable of surviving the extremes of temperatures and salinity which it encounters on Oahu, a survey of these factors in tide pools and brackish areas known to be penetrated by the species was undertaken and compared with the tolerance of the species to these factors as determined by laboratory experiments on both juveniles and adults.

Environmental Extremes

The survey of environmental temperature and salinity was not made on any regular schedule. Only when conditions occurred which suggested that high and low values of temperature and salinity might be found, were measurements of these factors made. Temperatures were taken at mid-depth of the tide pools tested. Water samples from which chlorinity was determined were obtained after stirring the pools. The Mohr method was used to determine chlorinity, and the results are expressed as grams of chlorine per kilogram of sea water (‰).

The maximum temperature, 35.1° C., was recorded in a tide pool with basalt bottom (almost black) at Makapuu Point on August 31, 1953, at 2:00 P.M. A reverse stratification of temperature existed in the pool at that time. A +0.2 low tide had occurred at 1:50 P.M. The maximum air temperature at Makapuu Point for August 31 was 79° F. (26.2° C.). Other fishes observed in the tide pool along with manini included aholehole (*Kuhlia sandvicensis*) and kupipi (*Abudefduf sordidus*).

The minimum temperature, 16.2° C., was recorded in a small tide pool at Diamond Head on March 5, 1954, at 11:15 P.M. A –0.2 low tide had occurred at Honolulu at 10:42 P.M. The minimum air temperature during the night was 60° F. (15.5° C.). A strong northerly wind was blowing. The wind velocity for the hour prior to the temperature reading was as high as 33 knots.

The extremes of environmental temperature recorded by Tester and Takata (1953: 48) for the aholehole on Oahu are 20.1° C. and 32.1° C. Like the manini, young aholehole are tide-pool residents. Although found in the highest pools of the intertidal zone, they are less inclined than the manini to enter small pools. A more notable difference of these two species is the ability of the aholehole to live in streams with little or no salt content.

The lowest chlorinity recorded from pools where manini were observed was 2.65 ‰. This reading was obtained from a high tide pool at Diamond Head during a heavy rain at 9:00 A.M. on March 1, 1954. A +0.1 low tide occurred at 9:02 A.M. A rivulet of rain water was observed entering the pool.

Another low chlorinity (3.62 ‰) was obtained in a sample taken from the shore of the Ala Wai Canal at the Ala Moana Bridge on February 23, 1954, following a heavy rain. Although manini could not be seen at the time because of the turbidity of the water, they were observed in the area prior to the rain and after the water had cleared.

The highest chlorinity was 21.30 ‰. The water sample was taken from the pool at Makapuu Point in which the 35.1° C. temperature was recorded.

Experiments on Temperature Tolerance

The experiments on temperature tolerance were performed on manini which were maintained in aquaria at a near-constant temperature of 24° C. for at least 24 hr. The fish were placed singly in a gallon jar of sea water at the temperature of the aquarium from which they were taken. The jar was then lowered into a water-filled copper compartment containing either a heating unit or a refrigerating unit and brought to the test temperature in 1 hr. ± 10 min. The fish were kept at this temperature for 1 hr. If death ensued before the end of this hour, the time was recorded. The duration of the test period was chosen as a rough approximation of the temporal conditions of exposure to temperature extremes experienced by manini in high tide pools. Throughout the tests the jar was strongly aerated.

At about 5° C. before the maximum or minimum temperatures were reached, the fish began to increase their rate of swimming and darted around the jar. As the lethal temperature was approached more closely, the equilibrium of the fish was affected. They swam on one side, upside down, or in small circles. The last major activity was usually a rapid, spasmodic, swimming movement, often in a short spiral.

The results, except those of tests of both juveniles and adults run at temperatures of 36.5° C. or less and 13° C. or greater (which caused no deaths), are shown in Table 1.

Although the data are not adequate to determine individual variation in the region of the temperature extremes, it seems evident that a range of about 13° to 36° C. is withstood by this species in the Hawaiian Islands, disregarding the possible extension of this range by acclimatization.

TABLE 1

TEMPERATURE TOLERANCE OF *Acanthurus triostegus sandvicensis*

STANDARD LENGTH (mm.)	TEST TEMP. (° C.)	MINUTES TEST TEMP. ENDURED
96	37.0	45
97	37.0	60
137	37.5	25
96	37.6	10
86	38.0	4
97	38.0	15
101	38.2	6
103	38.3	20
26	36.8	40
27	37.2	60
28	37.5	60
34	37.6	15
29	37.8	60
28	38.0	60
29	38.0	18
28	38.1	2
103	13.3	60
95	12.2	60
140	10.1	10
122	9.0	2
25	13.6	2
27	12.8	10
27	12.5	60
28	11.6	5
27	11.0	60
32	10.8	8

Although the range of temperature which manini can withstand appears to be extralimital to the extremes normally encountered by the species in the Hawaiian Islands, information supplied by D. W. Strasburg in a letter suggests that juvenile manini in the southern Marshall Islands are, upon occasions, killed in tide pools by heat. On August 17, 1950, a high tide pool, about 30 sq. ft. in surface area and 1 ft. deep, on the ocean side of Arno Atoll was observed at low tide to contain two small *Acanthurus triostegus triostegus* and one small *Istiblennius edentulus*. Several hours later the two manini were dead. The blenny was still living. The temperature of the pool at mid-depth was 41° C.

Experiments on Salinity Tolerance

Salinity tolerance experiments on manini were carried out in a 30 gal. aquarium. All fish were retained in aquaria at least 24 hr. before use in experiments. The fish were not exposed to the test salinity suddenly. Instead the salinity was gradually changed over a period of 2 hr. either by the removal of aquarium water and replacement with tap water (previously allowed to stand for at least 12 hr.) or the addition of salt from evaporated sea water. Fish were held at the test salinity for a maximum of 24 hr. The long period of exposure to salinity extremes was chosen because manini entering brackish areas may be subjected to water of low salt content for at least this length of time.

The results are given in Table 2. Omitted are trials run at chlorinity values greater than 1.4‰, none of which caused any deaths. No trials were run at chlorinities greater than 38.25 ‰.

Although more data are needed to determine with accuracy the minimum salinity which manini can withstand, it seems evident that manini in tide pools can tolerate a greater range in salinity than they normally experience. Since they cannot live in water of extremely low salinity, they probably do not enter fresh-water habitats.

PREDATORS

Predation on the manini is probably most acute during the early stages of the life history, but I have no information on the identity of the many pelagic animals that must feed on the eggs and small larvae. The large number of post-larval stages of acanthurids found in the stomachs of adult yellowfin tuna has been discussed.

Only a few instances of predation on juvenile manini have been encountered incidentally and are presented here briefly. Juvenile manini have been found in the stomachs of moray eels (Muraenidae). A small lizard fish (Synodidae) was observed to catch a juvenile manini in its jaws in shallow water in Kaneohe Bay, Oahu. The manini was too large to be swallowed, and it eventually escaped. A 50 mm. specimen of *Antennarius* was placed in an aquarium with six juvenile manini. A half hour later it had eaten one of them (length, 31 mm.).

In the Society Islands a juvenile *Caranx melampygus* about 90 mm. long was observed from shore to capture a small *Acanthurus triostegus triostegus* 25–30 mm. in length. This carangid occurs in the Hawaiian Islands where it probably feeds in part on manini, as may other species of *Caranx*.

Also in the Society Islands, the young *Acanthurus triostegus triostegus* have been found in the stomachs of the groupers *Epinephelus merra* and *Cephalopholis argus* and the snapper *Lutjanus vaigiensis* (Randall and Brock, 1960).

It is believed that predation (man excluded) on the juvenile stage of the manini in the Hawaiian Islands is much more pronounced than on the adult stage. In addition to the fishes mentioned above, holocentrids, scorpaenids, cirrhitids, and sphyraenids, and possibly also certain

TABLE 2

SALINITY TOLERANCE OF *Acanthurus triostegus sandvicensis*

NO. OF FISH	STANDARD LENGTH (mm.)	CHLORINITY (0/00)	NO. SURVIVING 24 HR.	MAXIMUM HR. SURVIVED
3	26–29	1.4	3	
4	26–29	0.7	0	5
3	27–29	0.1	0	less than 5
1	92	1.4	1	
1	89	0.7	0	8
2	86–90	0.4	0	between 3 and 15
3	27–29	34.8	2	
4	26–28	35.7	2	
3	28–29	37.4	2	
4	26–29	38.25	0	5
1	83	38.25	0	17.5

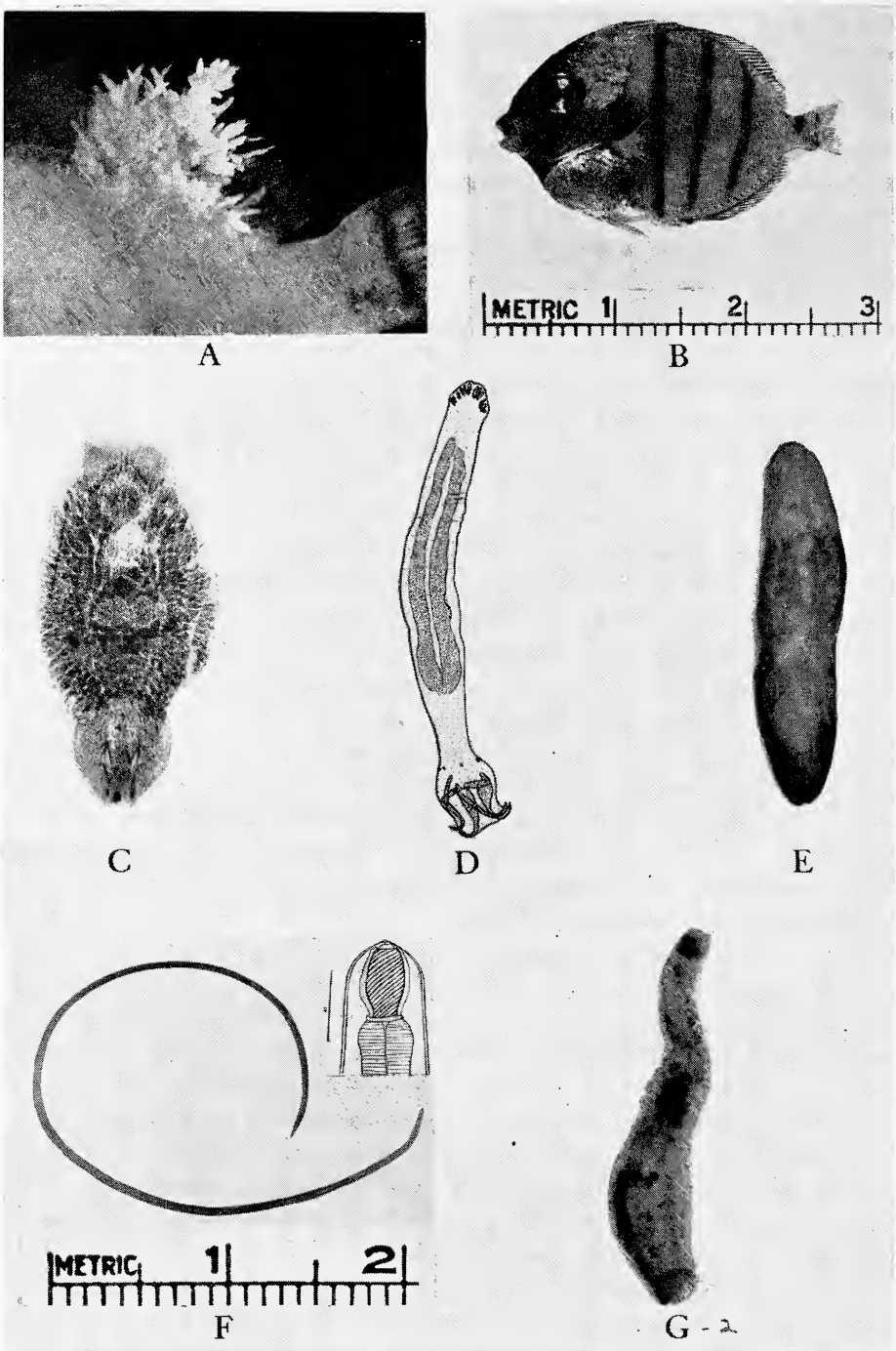

FIG. 2. Parasites of *Acanthurus triostegus sandvicensis*. *A*, Colony of *Hydrichthys* sp. on the dorsal fin of a manini in its first day of transformation from the acronurus to the juvenile state. *B*, *Hydrichthys* on the post-orbital part of the head of a manini in its second day of transformation. *C*, *Benedenia* sp. from the epidermis of an adult manini; length of trematode, 1.9 mm. *D*, *Ancyrocephalus* sp. from the gills of manini; length of trematode, 0.63 mm. *E*, *Hapladena varia* Linton from the duodenum of an adult manini; length of trematode, 2.9 mm. *F*, Adult female *Spirocamallanus monotaxis* Olsen from the intestine of adult manini; insert shows anterior end of the nematode (after Olsen, 1952); red in life, the females attain a length of about 45 mm. and the males about half this size. *G*, Unidentified leech (possibly *Johanssonia* sp.) from the gills of a manini; length of leech, 2.4 mm.

of the larger nocturnal crabs, may feed on small manini. Once a manini reaches adult size, it probably enjoys freedom from predation by most of these fishes in Hawaii, for the inshore marine fauna is peculiar in the paucity of moderately large carnivorous fishes. Shallow-water serranids and lutjanids, many of which are well adapted to prey on reef fishes, were almost totally lacking in the Hawaiian Islands until the recent effort to introduce some of these fishes. The larger native predaceous fishes, such as adults of *Caranx*, *Sphyraena*, and sharks, are not numerous at the present time, probably because of fishing pressure.

PARASITES

Seventeen species of parasites were detected on and within the manini.

Seven specimens of transforming manini were found to be parasitized by *Hydrichthys* (Fig. 2*A*), probably *H. mirus* Fewkes. This unusual hydroid occurred on the head, body, and fins and apparently does not have a preferred attachment site. It was never seen on juveniles or adults. Probably it flourishes only on postlarval manini, for it appears to be abraded and regressing on most of the transforming fish (Fig. 2*B*).

Three specimens of a monogenetic fluke (*Benedenia* sp.) were discovered on the epidermis of two adult manini. The flukes are small (less than 2 mm. in length), perfectly transparent in life, and were hidden in the slime of the fish. They are difficult to find and are probably more common than the few specimens would indicate. Figure 2*C* is a photograph of a stained specimen. Jahn and Kuhn (1932) have worked out the life cycle of *Benedenia melleni*.

The most common fluke of the manini is an unidentified species of the gyrodactylid genus *Ancyrocephalus*. Figure 2*D* is a drawing of a living specimen, 631 micra in length, which was obtained from the gills of a 132 mm. manini. This very small species of trematode was found on the gills of most of the manini which were examined. In some of the manini the infestations were heavy, an average of about one fluke per gill filament being present. It is extremely active and highly extensible and was observed to change its position on a gill filament by attaching with the anterior end and looping the posterior end over to another location where the hooks were dug into place. Siwak (1931) reported on the life cycle of a species of *Ancyrocephalus*.

Two digenetic trematodes were found in the digestive tract of the manini, *Hapladena varia* Linton and *Haplosplanchnus obtusus* (Linton), previously known only from the surgeonfishes *Acanthurus hepatus* (= *chirurgus*) and *Acanthurus coeruleus* at Tortugas, Florida. Manter (1955: 76) included a discussion of this distribution in a recent paper reviewing the zoogeography of trematodes of marine fishes.

Hapladena varia (Fig. 2*E*) was only occasionally found in the intestine of the manini. A total of 22 specimens, usually less than 3 mm. in length, were taken from 200 manini whose digestive tracts were examined for parasites. The manini harboring the flukes ranged from 43 to 136 mm. in standard length.

Haplosplanchnus obtusus was found only in juvenile manini, although it may have been overlooked in adults. It is smaller than *Hapladena varia*, usually less than 1.3 mm., and not as slender. Some of the juvenile manini contained a large number of these flukes. Seventy-one were counted in one 49 mm. specimen. Most of the flukes were in the duodenum, a few extended as far back as the halfway point of the intestine, and a few were found in the pyloric caeca.

Four different nematodes were found in the manini. Two could not be identified to genus. One of these was a very attenuate immature male from suprapharyngeal tissue of the fish. The other was represented only by larval specimens from the pyloric caeca. A third worm, which was occasionally found encysted in the mesenteries, was considered to be the immature female of an unidentified species of *Contracaecum*.

The fourth nematode, *Spirocamallanus monotaxis* (Fig. 2*F*), was described by Olsen (1952) from the sparid fish *Monotaxis grandoculis*, reportedly a mollusk-feeder. In all probability this roundworm will be found in other Hawaiian fishes.

Of 200 manini (mostly adults) from Oahu examined throughout the year for internal parasites, 76 were found which harbored *S. monotaxis* in the intestine or pyloric caeca. The av-

erage number of worms found in these 76 fishes was 5. The largest number of worms in a single fish was 35. No obvious variation of the degree of infestation of this nematode in the manini was observed during the year.

Two different leeches were found on the manini. Both are species in the family of Pisicolidae (possibly genus *Johanssonia*). One is represented by a single 2.4 mm. immature specimen (stained and photographed herein as Fig. 2*G*) which was taken from the gills of an adult manini. Six specimens of the other leech were collected from the body surface of three juvenile manini, 26–31 mm. in standard length, taken in the Ala Wai Yacht Basin on April 17, 1955. These leeches varied from 2.9 to 7.5 mm. in length, were dark brown in life, and easily detected on the host.

Six species of parasitic copepods have been taken from the body surface and pharyngeal cavity of the manini. *Lepeophtheirus dissimulatus* Wilson was the species most commonly encountered: 112 of 164 adult manini examined for parasites throughout the year were infested with from 1 to 20 of these copepods. The other parasitic copepods found were two species of *Caligus*, a *Dentigryps* sp., *Peniculus minuticaudae* Shiino, and *Nessipus costatus* Wilson, which encysts in the fins. A comprehensive report on these and other parasitic copepods from Hawaiian acanthurid fishes is being prepared by A. Lewis.

A mutualistic association was observed between the manini (and other reef fishes) and a small colorful wrasse, *Labroides phthirophagus* Randall. In the clear water off Manana Island two adult manini were seen being pecked over the head and body by this wrasse. The manini remained motionless in the water except for slight undulation of the fins. Since the stomach contents of several of the wrasses consisted primarily of calagoid copepods, it is believed that the fish were removing crustacean ectoparasites from the manini. On another occasion a manini was observed to swim directly to the "domain" of two of these labrids. As the manini was approached by one of them the surgeonfish was speared and brought ashore. Two adults of *Lepeophtheirus dissimulatus* were visible on its body.

DISEASES

The only data on disease were obtained from a series of unsuccessful attempts to maintain manini in an aquarium. Four adult fish were placed in a 23 gal. stainless steel aquarium which had previously been used to keep adult and juvenile manini for periods of several weeks. The water was aerated and filtered. Two days later two of the fish died, and on the following day the remaining fish were dead. Several hours before their death the manini swam in a disoriented manner. The fins were badly eroded. The head and body were excessively slimy, and large scattered sores were present. The fish were examined for parasites and found to have no more than the average complement.

The tank was cleaned (but not sterilized) and two more adult fish added. They died in a similar fashion in 48 hr. The tank was again cleaned and a 57 mm. juvenile manini placed in it. This fish died just 48 hr. later.

In spite of the filtration, the tank became cloudy on the second day after cleaning. A milliliter of the water was taken, successive dilutions made, and the higher dilutions cultured with a sea water and agar mixture (sterile aged sea water, agar, and a small amount of peptone and ferric phosphate). The number of resulting bacterial colonies were counted; the bacterial count of the original milliliter of aquarium water was computed at 212,000,000. Before the fish were placed in the aquarium the number of bacteria were probably less than 1,000,000 per ml.

Several smears were taken from eroded areas of dying manini. The dominant organism was a short, plump, gram-negative rod. It is not known whether this is the etiological agent of the disease or merely a secondary bacterium.

FOOD HABITS

Food of Larval Manini

Only three specimens of larval manini (6.6–7 mm. in total length) were available for an analysis of gut contents. Two of these fish were taken in a plankton net towed between 5:46 and 6:48 A.M. One was empty and the stomach of the other contained two appendicularian tunicates and a larval polychaete. The third fish

was captured between 3:20 and 4:25 A.M. and was empty.

The digestive tracts of 57 manini in the acronurus stage (see section on transformation), which were obtained at night light stations in the Hawaiian Islands, Line Islands, and Phoenix Islands, were examined in the same way. Forty-five were completely empty. Four contained one to seven tiny fish scales; one of these also contained a shrimp chela. A few crustacean appendages (mostly from shrimp) were found in three other fish, one of which had also eaten a barnacle metanauplius. The intestines of two fish had a small amount of unidentified chitinous remains. The crustacean appendages, metanauplius and fish scales were not free in the gut lumen but were caught between longitudinal folds of the gut. It seems evident that the acronuri do not feed at night.

Four acronuri of *Acanthurus* were obtained from the stomachs of skipjack (*Katsuwonus pelamis*) caught during the day in Hawaiian waters. Because of their being partially digested, I am not able to identify any of these acronuri to species; two, however, are too large to be manini. The stomachs and intestines of all four of these fish were filled with zooplankton. Shrimps and shrimp larvae were the principal food items. Also found were copepods, polychaetes, and the remains of larval fish.

Food of Transforming Manini

In an aquarium, manini in their first day of transformation from the acronurus to the juvenile stage were not observed to feed. The digestive tracts of 30 specimens, collected in tide pools during the morning of their first day of transformation and preserved immediately, were devoid of food material. Of 24 similar specimens collected in the afternoon, 19 were empty, but 5 had eaten small amounts of fine filamentous algae and leptopel (for a discussion of leptopel see Fox, Isaacs, and Corcoran, 1951). Second-day transforming manini were seen to feed on algae in an aquarium, though not frequently, and preserved specimens of the same transformation age all contained small amounts of algae and leptopel. During the remaining 2 or 3 days of transformation, feeding is progressively heavier.

Food of Juvenile and Adult Manini

The gut contents of juvenile and adult manini consist almost entirely of relatively fine filamentous algae. The teeth of the manini are close-set and denticulate on the margins (Randall, 1956 *b*: fig. 2a) like other species of *Acanthurus*. They are therefore well adapted for feeding on filaments of algae. Experiments on feeding in aquaria showed that the absence of coarser algae in the gut contents is due to limitation in the size and strength of the jaws and teeth. Only the smaller branches of coarser algae, like species of *Hypnea*, were eaten. Small juvenile manini only ate the fine end branches whereas larger fish ate progressively larger branches.

Inorganic sediment was rarely found in the stomach or intestines of manini. When branches of a delicate species of the red alga *Polysiphonia* were mixed with fine sand and offered to aquarium manini, the fish were most adept at picking out the filaments which projected above the sand. The stomach of the manini is thin-walled, similar to that figured and described by Breder and Clark (1947: 295, fig. 1) for *Acanthurus coeruleus*. It contrasts sharply with the thick-walled, gizzard-like stomachs of some species of *Acanthurus*. Unlike the manini, the latter species normally ingest large amounts of inorganic sediment with the algae upon which they feed.

In addition to avoiding the ingestion of inorganic debris, juvenile and adult manini do not seem to feed on animal material (although some species of *Acanthurus*, such as *A. xanthopterus*, will accept animal food readily). Even when hungry, manini declined to eat any of several kinds of animal food which were offered. In an aquarium the fish were very skillful in avoiding the intake of small crustaceans and small masses of tunicates or sponges which were in close proximity to the algae on which they were feeding. Occasional small animals are found in the gut contents, however. These are probably taken in accidentally. In shallow water at Coconut Island, Oahu, an adult manini was observed feeding on algae close to an egg mass of the damselfish, *Abudefduf abdominalis* (the guarding fish had been frightened away). When the manini reached the edge of the egg mass, it ceased to feed, swam over the mass, and began feeding on algae on the other side. Other fishes,

such as labrids and chaetodonts, feed greedily on the eggs when afforded the opportunity to do so by the absence of the guarding parent.

A study of the kinds of filamentous algae eaten by manini was undertaken. It was soon apparent that a great many different species of algae are eaten, and it is believed that at least a few filaments of virtually every filamentous alga in the Hawaiian area can ultimately be found in the gut of the manini if enough specimens are examined.

Dawson, Aleem, and Halstead (1955: 21), reporting on the gastrointestinal contents of 42 *Acanthurus triostegus triostegus* (size of specimens not given) from Palmyra, Line Islands, found 40 species of benthic algae and a number of species of diatoms of several genera. The number of algal species exceeded that previously known from Palmyra. Five species were most common in the stomachs: *Pterocladia* sp., *Sphacelaria furcigera*, *Lyngbya majuscula* (and/or *L. aestuarii*), *Bryopsis pennata*, and *Lophosiphonia* sp. The authors assumed that these were either dominant algae in the grazing grounds of the fish or were especially selected as food. It is the opinion of this author that these are the dominant algae, for (as is discussed below) the blue-green *Lyngbya majuscula* and another *Lyngbya* are not selected by this surgeonfish (at least not the Hawaiian subspecies).

A simple piece of apparatus was devised to test the preference by manini in Hawaii for various kinds of common filamentous algae. Ten tongue depressors were attached 2 cm. apart to a piece of wood. The free end of each depressor was notched and wrapped with a short piece of pliable galvanized steel wire. Different kinds of algae were fastened to the depressors by wrapping the wire ends around them. All 10 depressors with the assortment of algae attached were lowered simultaneously into the center of an aquarium in which juvenile manini, 26–30 mm. in standard length, were kept. When experiments were repeated, the position of the algae was always changed. If an alga was not eaten during the course of the experiment, it was left in the aquarium as long as it appeared edible to see if it would ultimately be devoured. The results are given in Table 3.

Many of the above algae were offered in a comparable manner to two adult manini, 123 and 128 mm. in standard length, with similar results.

Some species of algae not listed in the table were offered but not eaten; these, however, were probably too coarse for the juveniles. Included were two species of *Laurencia*, a species of *Gelidium*, a *Gracilaria*, and a species of *Dictyota*. A thallus of one of the species of *Laurencia* was placed in the aquarium with the adult manini. The small branches were eaten, leaving the major branches denuded.

Of the seven kinds of algae fine enough to be eaten but ignored in the preference experiments, one is a red (*Asparagopsis taxiformis*, well known for its high iodine content), one is brown (*Ectocarpus breviarticulatus*), and the rest are blue-greens. These were the only blue-greens tested.

Blue-green algae, some of which are the same species as those in the preference experiments, have been found in the stomachs and intestines of manini by the author (and, as noted, by Dawson, Aleem, and Halstead, 1955). This seems inconsistent with the results of the experiments. It was noted, however, that the blue-greens were never the exclusive food material, but were always mixed with large amounts of other algae, usually reds or greens.

In May, 1952, in water 10–20 ft. deep in Hanauma Bay, Oahu, the bottom was examined for the kinds of fine algae which reach a height of about 5 cm. or more. Three species this size were common: *Lyngbya majuscula*, *Asparagopsis taxiformis*, and *Plocamium sandvicense* (a red alga). Since surgeonfishes are abundant in the bay and at least two of the three algae are distasteful to one surgeonfish, the success of these algae might be associated with distasteful qualities.

Although there was little question from the observations that the manini requires no animal food, an experiment was designed to demonstrate that this species can subsist and grow on algae alone. A 23-gallon aquarium was divided into two compartments with a piece of plexiglass. Six manini, 26–31 mm. in standard length, were placed on each side and provided with cover in the form of several rocks grouped in the center of each compartment. The fish on one

TABLE 3

PREFERENCE FEEDING EXPERIMENTS ON JUVENILES OF *Acanthurus triostegus sandvicensis*

PREFERRED	COMPLETELY EATEN	SPARINGLY EATEN	NEVER EATEN
Polysiphonia sp.	*Hypnea* sp.	*Ectocarpus indicus*	*Lyngbya majuscula*
Enteromorpha sp.	*Hypnea* sp.	*Sphacelaria* sp.	*Lyngbya* sp.
	Lophosiphonia sp.	*Liagora* sp.	*Hormothamnion enteromorphoides*
	Ceramium sp.	*Jania* sp.	*Hydrocoleum cantharidosmum*
	Centroceras sp.	*Rosenvingia* sp.	*Calothrix confervicola*
	Gracilaria sp.	*Trichogloia* sp.	*Ectocarpus breviarticulatus*
	Rhizoclonium sp.	fixed diatoms (many species)	*Asparagopsis taxiformis*
	Dasya sp.		
	Enteromorpha sp.		
	Cladophora sp.		
	Grateloupia sp.		
	Herposiphonia sp.		
	Microdictyon setchellianum		

side were fed with a *Polysiphonia* and those on the other with an *Enteromorpha* (these were the algae upon which manini fed most vigorously in the preference experiments).

These algae are among the first macroscopic organisms to appear on the bottom of boats in harbor areas on Oahu. They are fast growing, especially the *Enteromorpha* which increased its length an average of 27 mm. per day on the eastern side of a boat during a period of 5 sunny days in April. If collected when the thalli first develop, they are almost devoid of animal life. A fresh mass of the *Enteromorpha* weighing 1.75 g. contained one ciliate, one nematode, one copepod, and a few epiphytic pennate diatoms and blue-green algal cells. Nevertheless the algae were thoroughly washed and picked over for animals before being fed to the fish. Fresh algae were added to the aquarium every day, and the previous day's algae removed. At the end of 2 weeks the fish were measured. Those fed on *Polysiphonia* grew an average of 2.9 mm.; those fed on *Enteromorpha* grew an average of 3.1 mm. During the 2-week interval the temperature in the aquarium was cool, varying from 23.0° to 23.8° C.

The preference experiments indicated that neither of these algae was eaten more readily than the other. Manini often alternated between feeding on the two. After 2 weeks of feeding on one of these, both kinds were added at the same time. It was immediately apparent that the fish had been conditioned to the alga on which they had been feeding. The "new" alga was untouched initially and only occasionally sampled an hour later. The preference was no longer obvious by the end of the day, however.

Manini feed almost constantly during the day, both in an aquarium and their natural habitat. They do not feed at night (see section on behavior).

The volume of algae consumed is large. Four juvenile manini, 28.5–45 mm. in standard length and weighing a total of 8.3 g., were fed a known mass of *Enteromorpha* in an aquarium early in the morning. The alga was weighed after firm squeezing followed by blotting on paper towels. At the end of the day the remaining fresh algal material was weighed in the same manner. Fresh *Enteromorpha* is grassy green and can easily be distinguished from fecal alga which is brownish or blackish green and tends to remain in pellets. The manini ate 10.8 g. of this alga one day and 8.8 g. the next. The same procedure was utilized for two adult fish, 123 and 128 mm. in standard length and 83.2 and 94.5 g. in weight, respectively. These two fish ate 27.4 g. of *Enteromorpha* in one day. The second day 16.3 g. of *Polysiphonia* was consumed. After being unfed during the morning of the third day, they ate 25.2 g. of *Enteromorpha* during the remaining 6 hr. of the day. Although these two adult manini in the above experiment were well adapted to aquarium life (they were reared to this size as captive fish in a pond of the Hawaii Marine Laboratory at Coconut Island and were

maintained in the aquarium 12 days before the experiments), it was observed that they did not feed as frequently as adult manini in the natural environment (whereas the juveniles did). The feeding by the adults was readily interrupted by the approach of an observer. Usually only one fish fed at a time, and since the larger one dominated the smaller and held it in a corner of the aquarium for much of the day, the former consumed the major part of the algae. Yet both fish disdained to feed at all when placed in separate aquaria.

Stimulus to Feeding

The following simple experiments and observations were conducted in order to ascertain what sensory mechanism or mechanisms are utilized by the herbivorous manini in finding food.

The juice from several grams of *Enteromorpha* was squeezed into an aquarium in which two adult manini had been starved for a day. This was unfiltered and colored the water green when first dropped into the aquarium. No response was observed, even when some of the green color was seen to diffuse in the immediate vicinity of the nose and mouth of the fish. A similar experiment was performed on several juvenile manini with *Polysiphonia*, again with no visible response. By contrast, when an extract of *Polysiphonia* was dropped into an aquarium containing a half-grown *Abudefduf abdominalis* (omnivorous in food habits), this fish swam to the surface where the extract clouded the water red and snapped its jaws erratically in this region.

Some *Enteromorpha* and *Polysiphonia* was boiled to the extent that the algae began to disintegrate and lost most of their color. This was placed in the aquarium with fresh algae of the same kinds. Although juvenile manini fed initially on the fresh algae, the boiled algae was ultimately completely eaten.

Some maroon rayon fiber similar in texture and color to *Polysiphonia* was placed in an aquarium with juvenile manini. It was taken into the mouth temporarily by several of the fish. When the rayon was soaked in extract of the *Polysiphonia*, it was not taken in with greater frequency.

When recently voided fecal *Enteromorpha* was placed at the surface of the aquarium in the same manner that fresh algae were offered, most of the manini approached it, hesitated, and swam away. One juvenile drew a small amount into its mouth but hastily ejected it. When defecated filaments were added together with fresh filaments of *Enteromorpha*, only the fresh alga was eaten. In the absence of fresh algae, fecal algae which have remained in the aquarium for several hours may be ingested. The results of offering the blue-green algae listed in Table 3 were similar to that just described for recently voided fecal algae. The blue-greens were approached, but rarely taken into the mouth.

The nasal organs of a 26 mm. manini were cauterized with a hot wire. Five min. after this, the fish was offered some *Polysiphonia*. It fed on this with the same "enthusiasm" as previously.

Another juvenile fish was blinded by wiping a crystal of potassium hydroxide over the eye (other fish were blinded with silver nitrate crystals but these invariably died within 36 hr.). After contact with the potassium hydroxide, the surface of the eye became opaque white; this fish survived more than 3 days. It moved slowly about the bottom, occasionally swimming by chance into a mass of *Polysiphonia*. It never swam directly to the algae. When the algae touched the mouth it was often eaten. By the third day when the aimless movements carried the fish into a mass of algae, it fed voraciously.

It is concluded from the above that vision alone is needed to locate algal food, and the olfactory sense functions in feeding only to avoid unsavory material. Chemoreceptor organs in the mouth and possibly tactile organs as well also seem to be associated with the acceptance of algae and the rejection of material which is not utilized as food. The tendency to feed more on one alga than another develops after the algae have been sampled.

DIGESTION

In the work on nutrition of marine animals much effort has been expended on the analysis of mode of feeding and stomach contents, whereas little has been applied to the important

aspect of the digestion of these animals. Yonge (1931) pointed out that information as to what an animal may collect and pass into its alimentary system may or may not indicate the true food of the animal. Thus, a study of digestion should logically accompany an investigation of food habits. The author is especially indebted to P. B. van Weel of the University of Hawaii for his counsel in the following research on digestion.

Morphology of the Digestive Tract

The similarity of the stomach of the manini to that of *Acanthurus coeruleus* as described by Breder and Clark (1947) has been mentioned. The manini stomach is elongate, and divisible into cardiac and pyloric portions. The cardiac part has prominent, longitudinal, irregularly scalloped folds on the inner surface; the pyloric part is smooth. A cross-section of the pyloric part showed the muscle tunic to be about the same width as the mucosa. There are few multicellular glands. The stomach wall is less than 0.1 mm. thick except posteriorly near the pylorus where it is slightly thicker than 1 mm.

Just posterior to the pylorus are five pyloric caeca. Several authors (including Yonge, 1931) have claimed that the pyloric caeca has taken over the role of the pancreas in certain teleosts, the latter organ supposedly being absent in these fishes. Dawes (1929) found that the pyloric caeca of the plaice (*Pleuronectes platessa*) had the same structure as the intestine with which it was in free communication, and Rahimullah (1945) came to the same conclusion after examination of 119 species in 50 different families of fishes. The structure of the pyloric caeca of the manini is consistent with the findings of Dawes and Rahimullah. The bile duct opens into the base of one of the pyloric caeca.

The pancreas of the manini was difficult to find. It was finally located in the form of two to four (usually three) small, round glands buff in color lying in the mesentery alongside the bile duct near its junction with the liver.

The intestine of the manini is long, in keeping with the well-founded biological principle that herbivorous animals have lengthy intestines. The length of the alimentary tract of large adult manini is nearly six times the standard length of the fish. Most of this length is attributable to the intestine which is complexly folded within the body cavity. The length of the alimentary tract of small juvenile manini is only slightly greater than three times the standard length of the fish. The increase of the alimentary tract relative to standard length is shown in the graph of Figure 3. With increasing size the volume of a body requiring nutriment increases faster than the intestinal surface if the rate of growth of the two is equal. A disproportionate elongation of the intestine is necessary to keep the area of absorptive surface adequate to the needs of the body. Hiatt (1947: 254, 257) noted a striking increase in the relative growth of the intestine of the herbivorous milkfish (*Chanos chanos*) between 90 and 115 mm. standard length. The ratio of intestinal length to standard

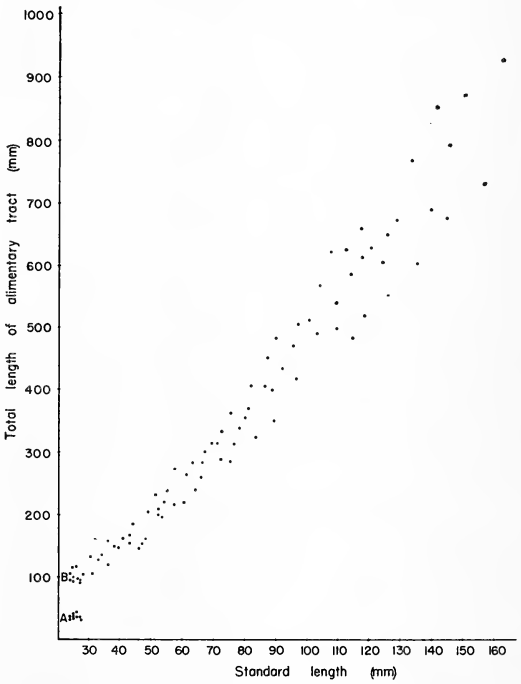

FIG. 3. Change in length of the alimentary tract of *Acanthurus triostegus sandvicensis* with increase in standard length. The group of points at *A* represents the length of the tract of 10 specimens (24–27.5 mm.) in the acronurus stage which were taken at a night light offshore. The points at *B* represent 10 tide-pool specimens (24–28 mm.) which have just completed transformation from the acronurus to the juvenile stage.

length increased from 3.5:1 to 7.2:1. He demonstrated a correlation between the increase in length of intestine and the substantial rise in the amount of larger algal types in the stomach contents and the reduced number of smaller food items like diatoms and blue-green algae. No sudden change-over in the size of algal food which is eaten by the manini occurs at any size range once transformation has taken place, and the curve of alimentary tract length plotted against standard length is without sharp inflection. The great increase of the gut length which occurs when manini transform from the acronurus to the juvenile state is discussed in the section on transformation.

The inner surface of the intestine is covered with small villi. The wall of the intestine is thin, its average thickness, not including any villi, is about 0.05 mm. The mucosa is about three to four times as broad as the muscle tunic.

Time for Algae to Pass through Gut

In order to find out the time which is required for algae to pass through the entire alimentary canal of the manini, two adults, 123 and 128 mm. in standard length, were fed only the red alga, *Polysiphonia*, for a period of 2 weeks. The tank was cleaned and the diet switched to the green alga, *Enteromorpha*. Two hr. and 25 min. later the fish were observed defecating the green alga. They had already deposited some on the bottom of the aquarium, so the following day the experiment was repeated by switching back to the red alga. In 2 hr. and 4 min. the first of the red alga was voided. In view of the great length of the digestive tract, this short interval of time seems extraordinary. However, when considered in the light of the nearly constant diurnal feeding and the volume of algae consumed, it becomes more understandable.

The same procedure was repeated for small juvenile manini, ranging from 26 to 30 mm. in standard length. The *Polysiphonia* passed through their alimentary tracts in 1 hr. and 45 min.

At night, when feeding ceases and the fish enter a state of torpor, the gut is not completely emptied in 2 hours or so. One 39 mm. manini, for example, which was caught at 1:15 A.M. still had a small amount of algae in the stomach and in the last 26 mm. of the intestine. The total length of the alimentary tract of this specimen was 177 mm. A 123 mm. manini was observed to defecate *Enteromorpha* 14 hours after it last fed on this alga.

Digestion of Algae

Lefèvre (1940) has shown that different kinds of algae resist digestion by gastrointestinal juices of fishes in various degrees. Although supporting growth of manini as well or better than the *Polysiphonia*, the *Enteromorpha* appeared less digested. Filaments of this alga were found to be only slightly altered after their rapid passage through the gut. The cellulose cell walls seemed unaffected, and the cell contents still in place. The only discernible change in most cells was the breaking up of the parietal grassy green chloroplast to brownish-green granular clumps. A visual comparison was made of the quantity of starch granules in the *Enteromorpha* cells following staining of fresh and fecal algae, and no obvious differences were apparent. Clearly, more work is needed to elucidate the problem of algal nutrition of the manini. The possibility that the pectic sheath material of algae is digested should be investigated.

Digestive Enzymes

No reference was found in the literature to any assay of the digestive enzymes of a strictly herbivorous fish. From work on herbivorous animals other than fishes the generalization can be made that proteinase is less active in herbivorous forms than in carnivores and amylase more active. There are indications that this is true for fishes, at least for amylase. Kenyon (1925) compared starch digestion in the carp (*Cyprinus carpio*) which, though omnivorous, eats large amounts of algae, and the carnivorous pike (*Esox lucius*). He wrote, "... the carp, which is largely a vegetarian, possesses amylase in tremendous amounts in the hepatopancreas and to a less extent throughout the intestinal mucosa. The pickerel, on the contrary, ... possesses only a negligible quantity of amylase, having little in the pancreas, esophagus, intestine, and practically none in the stomach." Vonk (1927)

wrote that the carp has more than 1,000 times the amount of amylase in the pancreas than that of the carnivorous pike or shark. Schlottke (1939) found amylase in large quantities in the carp, whereas the predaceous rainbow trout (*Trutta iridea*) and perch (*Perca fluviatilis*) evidently produced almost no amylase. Data comparing the activity of proteinase and lipase of omnivorous and carnivorous fishes are meager and conflicting.

In view of the importance of the hydrogen ion concentration to enzyme activity, the pH of the contents of various parts of the digestive system of the manini was determined. The measurements of pH were made with a Beckman pH meter on six adult fish which averaged 120 mm. in standard length. The results, expressed in the ranges of pH found, are given in Table 4.

The variation of pH within any one organ appears to be correlated with the degree of fullness of the organ. The low pH values were found in the organs when they were filled with algae. Hydrochloric acid secretion in a stomach in which food is present is a probable explanation for the greater acidity at this time. Babkin and Bowie (1928) found a variation in pH of the duodenum of the killifish (*Fundulus heteroclitus*) similar to that shown above for the manini. These authors also noted that low values of pH were obtained when the duodenum contained food. They attributed this to the discharge of bile to the organ when filled with food.

Extracts for the enzyme study were consistently prepared from the stomach (both cardiac and pyloric portions combined), pancreas, pyloric caeca, duodenum, and intestine of adult manini which were killed immediately before the removal of these organs. Because of the excessive thinness of the gut wall, it was very difficult to separate the mucosa from the muscle layers; therefore extracts were made of entire organs or linear parts of organs. All portions of the digestive tube to be extracted were first washed with sea water to remove food material. Tissues were ground in mortar and pestle with calcareous sand. This sand had previously been cleaned by repeated washings with water, boiling with 3 per cent potassium hydroxide and then for a short while with 2 per cent hydrochloric acid. In view of MacKay's (1929) report that

TABLE 4

pH OF ORGANS OF THE DIGESTIVE SYSTEM OF *Acanthurus triostegus sandvicensis*

ORGAN	RANGE OF pH
Stomach	6.3–7.7
Duodenum	7.7–9.1
Intestine	8.0–9.1
Gall bladder	6.2–6.4

30 per cent alcohol yielded the most active amylase from the eel pout (*Zoarces anguillaris*), this agent was also used to extract amylase in the present study. Lipase extracts were made in 40 per cent glycerol and protease extracts in 50 per cent glycerol. Extraction was carried out in a refrigerator for a period of 24 hr.

Digestion by amylase and lipase proved to be rapid at room temperature (26°–27° C.); thus no incubation was necessary in experiments with these enzymes. Digest tubes with protease were incubated at 36° C.

Buffer solutions used in the digestion experiments were based on the mixtures of Clark and Lubs (Hawk and Bergeim, 1942: 24). Bacterial action was prevented by the addition of several drops of toluol to the extract and digest test tubes.

The substrate for amylase experiments was 1 per cent starch solution. To each test tube containing 1 ml. of extract of the digestive organs 5 ml. of starch solution and 1 ml. of buffer of pH 6.8 were added. For each tissue there was a control tube identical with the experimental digest tube except for the previous boiling of the extract to inactivate all enzymes.

The progress of digestion was followed by removing small amounts of fluid from the digest tubes and testing with Lugol's solution. The changes in the solution from deep blue-black through purple, red, yellow, and finally colorless indicated a breakdown of the starch at least to achroodextrine. Ultimately all of the tubes were colorless, thus disclosing starch digestion by the pancreas, pyloric caeca, duodenum, intestine, and stomach. The experiment was repeated three times with sections of the digestive tract vigorously washed to minimize the possibility of enzyme from another source being adsorbed on the epithelial surface of the organ being tested.

Again, there was a definite amylase reaction from each organ.

The positive results seem unusual in view of the fact that most vertebrates (except for mammals which secrete ptyalin in their saliva) break down starch initially with pancreatic amylase and complete the process with intestinal maltase. These results on the manini seem less dubious, however, in the light of the finding by Kenyon of amylase throughout the whole gut of the carp (although it was considered to lack a true stomach) and by the detection of stomach and duodenal amylase in *Zoarces* by MacKay. Also Babkin and Bowie found amylase in the intestine of the killifish. They were certain it was not adsorbed pancreatic amylase, for they were unable to observe any proteolytic action in the same extract.

Pancreatic amylase of the manini is nearly 20 times more powerful per unit of tissue than the amylase from other organs, while that from the stomach was weakest (attempts were made to obtain extracts from equal amounts of glandular tissue of the organs under comparison).

The pH optimum of the amylase, as determined by color change with Lugol's solution and the micro method of Linderstrøm-Lang (Linderstrøm-Lang and Holter, 1933), is 6.7.

The Schoorl method was utilized to test for the presence of maltase in the stomach, pyloric caeca, pancreas, duodenum, and intestine of the manini. One per cent maltose solution served as the substrate. Trials for all organs were run at pH 7.0 and 7.2 and incubated at 30° and 35° C. for periods up to 12 hr., but results were consistently negative.

The method of Michaelis and Rona (see van Weel, 1937: 245) was used in lipase experiments. Tri-n-butyrin solution was used for the substrate. Digestion occurred rapidly in all the organs tested. It was evident that the pancreas produced the most lipase and the stomach the least, although the difference was not as marked as with amylase. The pyloric caeca showed the greatest lipase activity of the remaining organs. Difference between the duodenum and the rest of the intestine was not discernible. The pH optimum determined for pyloric caeca lipase of the manini is 7.2.

Detection of protein digestion was based on the formaldehyde titration of Sörensen (Jordan, 1927). The substrate was a 3 per cent colloidal solution of gelatin.

In initial experiments protease was found in the pancreas, pyloric caeca, duodenum, and intestine, but not in the stomach. In none of the organs was the proteolytic activity strong. The pH optimum of pancreatic protease is 8.4.

Because of the acidic reaction in the stomach of the manini and the knowledge that protease in this organ can vary widely from individual to individual depending on the state of hunger of the animal (Schlottke, 1939), further effort was expended to localize this enzyme in the stomach. Extract of high concentration (prepared from trituration in 5 ml. of 50 per cent glycerol of three adult manini stomachs, two of which contained considerable algae) finally gave positive results. One ml. of this concentrated extract (thus containing the extractable enzyme from three-fifths of a stomach) at pH 6.0 yielded acid equivalent to 0.2 ml. of 0.015 normal sodium hydroxide after 4 hr. of incubation.

A piece of the very thin covering (one cell layer thick) from one of the internal rings of an onion was peeled off and placed in a glass stender and covered with the fluid from the intestine of an adult manini. The onion skin was examined after 24 and 48 hr. periods, but no digestion of the cellulose cell walls occurred. The experiment was repeated with fluid from the intestine of another adult specimen, again with negative results. Thus there appears to be no cellulase-secreting micro-organisms in the intestine of the manini.

It is concluded that the results of the enzyme study of the manini are consistent with the generalization previously made concerning the digestive enzymes of herbivorous animals except for the absence of cellulase.

REPRODUCTION

Sex Ratio

No sexual dimorphism in external morphology was noted; therefore gonad examination was necessary for sex determination. The gonads lie in the ventroposterior part of the body cavity. No difficulty was experienced in distinguishing an ovary from a testis macroscopically except with immature fish. The ovaries are pinkish

cream in color, smooth, slightly compressed laterally, and closely applied to one another in the mid-line. The testes are white, strongly compressed, irregularly lobular, and in contact with each other only ventrally.

It was apparent from sampling the catch of trap fishermen throughout the year that approximately twice as many male manini as females were taken. In the month of May, 1953, 291 trap-caught adult fish were sexed; 68 per cent of these were males. The traps in which the fish are caught are unbaited. A typical trap consists of a rectangular framework (about $2 \times 5 \times 6$ ft.) of steel rod covered with chicken wire. A cone of chicken wire with a narrow slitlike opening extends inward from one end to about the center. Some trap fishermen prefer to leave one or two butterfly fish or other fishes of little economic value in the trap in the belief that other fishes will be more prone to enter. If male manini are more gregarious or less cautious or more migratory than females, they would be caught in traps with greater frequency than females; therefore sex ratios ascertained from trapped fish should be viewed with caution.

The sex was determined for 221 adult manini from islands in the tropical Pacific in the collections of the U. S. National Museum, the Bernice P. Bishop Museum, and the University of Hawaii. Most of these specimens were taken with rotenone, seine, and throw net. These collective techniques are less selective than traps and the sample would seem to be a better indication of true sex ratio. Of the 221 fish, 134 (60.7 per cent) are females. A chi-square value of 10 results from testing whether 134 females could be obtained from 221 fish randomly sampled from a population in which the true sex ratio is 50-50. This high chi-square has a probability greater than 0.01 that a sample more extreme than the above could be drawn by chance from a half male, half female population; thus the hypothesis of a 50-50 sex ratio is rejected.

It is nevertheless possible that the apparent predominance of female manini is spurious. Most of the 221 specimens were taken in inshore areas. The traps from which 198 males of 291 manini were caught were set in from 30 to 90 ft. of water. Perhaps females are more abundant in shallower water and the males predominate over deeper parts of the reef. More collections are needed to clarify this problem.

The museum collections of manini offer some slight evidence for differential schooling by sexes. One sample of 7 manini from the outer reef at Eniwetok Atoll, Marshall Islands, is entirely male; another of 12 fish from the lagoon of Kwajalein Atoll in the Marshalls is wholly female.

Spawning Cycle

The manini in the Hawaiian Islands has a distinct spawning season. This has been ascertained by the examination of the gonads of adult fish and collections of young throughout the year. In more equatorial areas, on the contrary, the spawning of this surgeonfish appears to be year-round. There is also evidence both in Hawaii and the Gilbert Islands that the pattern of the incoming young correlates with the lunar cycle. This is attributed to a lunar effect on spawning by adults.

From October 31, 1952, to October 27, 1953, a total of 137 female and 156 male manini 100 mm. or more in standard length were purchased in 41 samples from a fisherman for the purpose of examination of the gonads. The fish were caught in traps set in depths of 30–90 ft. from Kewalo Basin to Koko Head, Oahu. The length of the gonad on each side of the body cavity of each specimen was measured and the average length recorded. This average measurement was divided by the standard length and the quotient multiplied by 100. The range and mean of the resulting percentages are presented in Table 5.

Although the monthly samples are small, it is nevertheless apparent that the gonads of both sexes undergo a significant change in relative length during the year. They are largest in late winter and spring and smallest in late summer and early fall. The change which takes place in the ovary in late July and August is more complex than would be indicated from a mere shortening. The ovary (presumably following the last spawning) is red, flattened, and has a large lumen. Residual eggs are gradually absorbed (eggs being absorbed appear as amorphous masses of variable size), and the entire organ regresses to small size and a translucent gray color. There is

TABLE 5

GONAD LENGTH AS A PERCENTAGE OF STANDARD LENGTH BY MONTH, 1952–53

MONTH	NO. OF FEMALES	$\frac{\text{GONAD LENGTH}}{\text{STANDARD LENGTH}} \times 100$		NO. OF MALES	$\frac{\text{GONAD LENGTH}}{\text{STANDARD LENGTH}} \times 100$	
		Range	Mean		Range	Mean
Oct.	15	7.1–18.2	9.4	14	5.6–22.8	9.4
Nov.	2	7.7–14.4	11.1	12	8.3–22.8	15.5
Dec.	4	12.3–25.0	14.3	11	10.0–22.1	15.9
Jan.	9	8.6–25.6	13.5	10	8.4–25.0	17.9
Feb.	15	14.1–25.6	18.2	31	20.4–34.5	28.6
Mar.	19	13.5–32.2	19.3	25	12.8–35.7	28.6
Apr.	17	10.4–26.4	17.3	7	22.8–38.5	29.4
May	6	9.8–23.3	16.2	5	18.2–31.2	25.6
Jun.	9	7.0–34.5	13.5	5	15.0–25.1	20.0
Jul.	10	7.5–17.6	9.6	9	8.1–26.3	14.9
Aug.	9	5.5–11.9	7.2	8	6.5–23.8	13.2
Sept.	22	5.0–14.5	8.4	19	7.6–17.3	9.0

variation in the time when this occurs in individual fish, hence the ultimate small size is not apparent when the values of a number of fish are averaged by month. The ovary of a 145 mm. female taken on August 7, for example, was only 8 mm. in length.

The gonad measurement data are more significant in indicating a definite spawning season of the manini when coupled with the results of sampling the young throughout the year. Transforming and small juvenile specimens were absent from inshore areas during the fall and early winter months of 1952–53. Extensive observation and collecting were undertaken during the winter and early fall to ascertain the time of the first and last arrivals of acronuri from the pelagic realm. The first transforming young were sighted on February 14; the last of the season straggled in on October 6. In 1954 the first young were discovered on February 9. During my absence from the state, my wife and Philip Helfrich made an effort to determine the date of the last influx of young in 1954. In October only a single small juvenile was collected; it was taken on the 9th of the month and measures 27.5 mm. in standard length. It is completely transformed; therefore it had been in the tide-pool zone for about 5–8 days (see sections on transformation and growth). The first transforming young of the 1955 season were observed on January 27.

The time between the finding of the first ripe female of the season and the first incoming young and the time between the last ripe female and the last incoming young constitute estimates of the duration of larval life. The last ripe female of the 1952–53 season detected in the sampling program (see Table 6) was found on July 21. The first ripe female of the 1953–54 season was found on December 1. The last ripe females of this season were observed in the July 16 sample. The three estimates of the duration of larval life from the above data are 71, 78, and 83 days. Admittedly such estimates are subject to considerable error. Their average, 77 days, approximates 2½ months.

In order to obtain quantitative data on the recruitment of young to inshore areas of Oahu, a single large tide pool at Diamond Head (Fig. 4) was chosen for repeated collections of manini. This pool is nearly isolated at low tide. An overhanging ledge on the left (east) side of the pool provides excellent cover for the small fish. Pools as large as this but lacking such cover contain fewer manini. Each week at low tide the narrow outlet to the sea was occluded with a net, and all the manini in the pool were poisoned with rotenone. A total of 157 manini less than 30 mm. in standard length were taken from the pool during the season (Fig. 5). Nineteen specimens 30 mm. or longer were collected; these are presumed to have been in the tide-pool zone for more than one week (see section on growth) and hence are probably migrants from adjacent pools. They are not included in

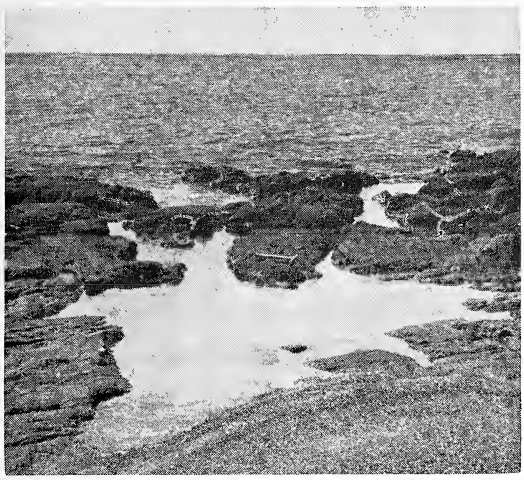

FIG. 4. Tide pool at low tide at Diamond Head, Oahu, from which the collections of *Acanthurus triostegus sandvicensis* of Figure 5 were made.

the graph of Figure 5. The poison stations on August 13 and August 21 were interrupted by unexpected large waves, and no fish were collected. However, on these two dates manini were counted in the pool before rotenone was added and these numbers are indicated by the dotted line on the graph. Probably there were at least twice as many small manini in the pool as are recorded, for most of the fish take cover rapidly when an observer approaches and are hidden before they can be counted. The sample of 36 fish taken on September 12, on the other hand, may be higher relative to the overall number of tide-pool young at this time than it should be. Observation of other pools at Diamond Head and along the shore of the Ala Wai Yacht Basin prior to, during, and after September 12 failed to disclose any striking influx of young. Nevertheless, the number of incoming young in September is high and this month should be included with the period May to August as indicating large tide-pool recruitment on Oahu.

Although this sampling from a single pool is not sufficiently great to be correlated closely with the similarly inadequate samples of adult gonads, the May to September recruitment seems to correspond roughly to the greater degree of gonad development from February to June.

In more equatorial waters the *A. triostegus triostegus* appears to spawn throughout the year. The 221 adult fish used for the sex ratio determination were collected mostly from the Mari-

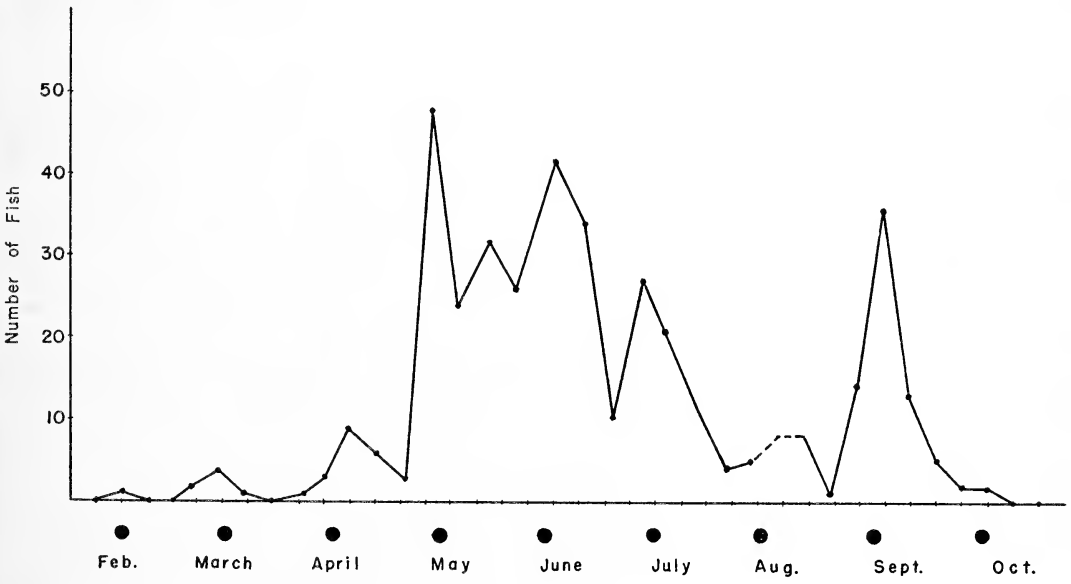

FIG. 5. Weekly collections of *Acanthurus triostegus sandvicensis* made in 1953 from a single tide pool at Diamond Head, Oahu. Only specimens 30 mm. or less are recorded. Times of new moon are indicated by black circles.

ana, Marshall, Gilbert, Line, and Phoenix islands—groups in which the sea surface temperature exceeds 80° F. (26.7° C.) the year-round and where the annual variation in sea temperature is slight (based on Hydrographic Office, 225). Examination of these fish revealed ripe gonads in every month of the year. Specimens of transforming or small juvenile manini collected every month of the year from these areas were found in museums.

It is, therefore, puzzling that the seasonal spawning in the Hawaiian Islands seems to be associated with the colder part of the year. The mean monthly sea surface temperatures around Oahu (1945–55) vary from about 75° to 81° F. in an average year (Leipper and Anderson, 1950; Hydrographic Office, 280.) The temperature of the warm part of the year is essentially the same as that of the lower latitudes where spawning is year-round. The initial enlargement of the gonads in Hawaii coincides with the time of decreasing sea surface temperature in the fall. The marked increase in tide pool recruitment in May appears to correspond to increased spawning in February–March, the time of coldest water temperature.

If temperature or some other factor such as change in length of day is the cause of interrupted spawning in Hawaii, then manini in a region of the South Pacific Ocean with comparable latitude should spawn seasonally and 6 months out of phase from Hawaiian manini. Unfortunately no data are available from southerly island groups such as the Australs or southernmost Tuamotus where sea temperatures closely approximate those in Hawaii.

Small juvenile and transforming *A. triostegus triostegus* were taken or observed by the author in every month of the year (1956–57) in the Society Islands (where temperatures range from about 77.5° to 81° F., or 25.2°–27.2° C.). The manini is not as abundant in the Society Islands as in Hawaii, and the insignificant tide in the former island group made it difficult to find numerous individuals isolated in tide pools. Collections were insufficient to demonstrate any possible variation in reproductive activity during the year.

A cyclic fluctuation in the abundance of incoming young within the spawning season in the Hawaiian Islands is apparent from Figure 5. The peaks of these fluctuations line up roughly with the time of new moon. This correlation is more evident from the extensive collections made from various tide pools plotted in Figure 6. The large mode of May 10 centered on a standard length of 26 mm. contains 54 transforming fish. The time of new moon was May 13. The large mode of April 17 is centered on a standard length of 27 mm. and contains 10 transforming manini. New moon in April occurred on the 13th day.

Tester and Takata (1953: 36, fig. 14) have demonstrated a similar lunar periodicity in the appearance of young aholehole (*Kuhlia sandvicensis*) in tide pools on Oahu.

If the periodicity in the influx of manini acronuri is a function of some lunar effect on the young and not on the spawning adults, then the peak fluctuations of incoming acronuri in areas of different temperature, and hence different rates of development (see development section), should still correlate with the time of new moon. A sample of 108 small manini collected with rotenone by the author from tide pools at Onotoa Atoll, Gilbert Islands, on August 21, 1951 (Fig. 7), demonstrates that this is not the case. Onotoa is located in the central Pacific (1° 47′ S., 175° 32′ E.); the monthly mean sea surface temperatures vary only slightly from 82.5° F. (28.6° C.) throughout the year. Full moon occurred on August 16 (new moon on August 2). The large mode of Figure 7 centered on about 23 mm. standard length includes only 9 transforming specimens which average 23.5 mm. in standard length. Thus the peak influx of the fish comprising this mode is estimated at 4 or 5 days prior to August 21. This large Onotoa sample, therefore, is about 11 days out of phase with the lunar cycle of incoming young on Oahu (where the mean monthly sea surface temperatures vary from 75° to 76.5° F., or 23.9°–24.5° C., from January to April).

In order to obtain direct evidence of lunar spawning by adult manini and to more sharply delimit the spawning season, the entire catch of two trap fishermen was examined for ripe fish on 62 days from June 19, 1953, to September 3, 1954. The catch was usually brought to port alive. The fishermen would not permit the open-

ing of the body cavity without purchasing the fish, but they allowed pressure to be applied to the abdomen of each manini.

When running ripe males (the sperm of which were motile) were discovered in samples taken throughout the year, it was realized that the limits of the spawning season could not be defined by the development of the male gonad. As would be expected from Table 5, however, there were more ripe males during the spawning season than outside of it. Of 745 adult manini (since trap caught, an estimated two-thirds were

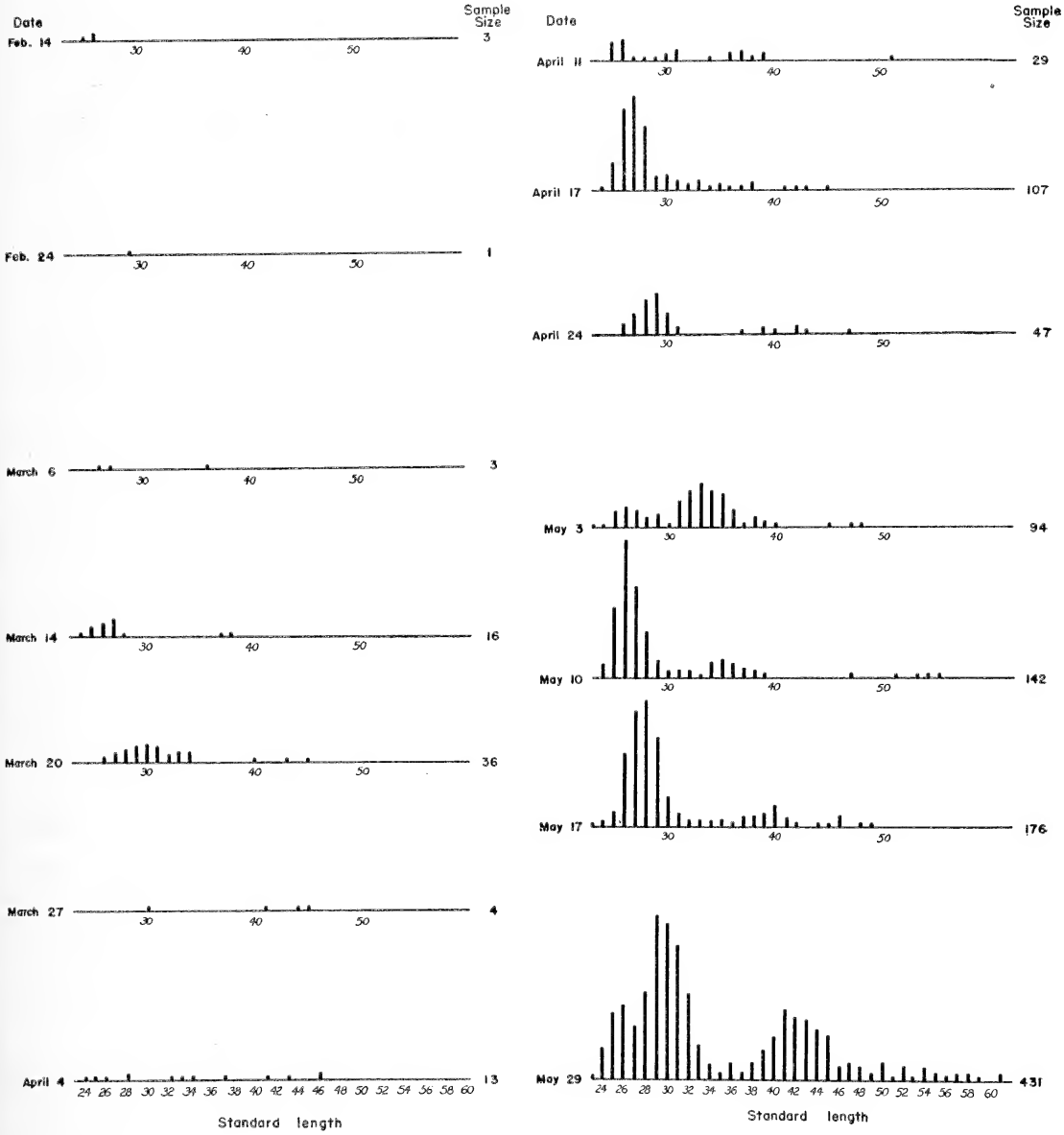

FIG. 6. Tide-pool collections of *Acanthurus triostegus sandvicensis* from Ala Wai Yacht Basin to Makapuu Point, Oahu, 1953. Vertical distance between horizontal lines is proportional to number of days between samples.

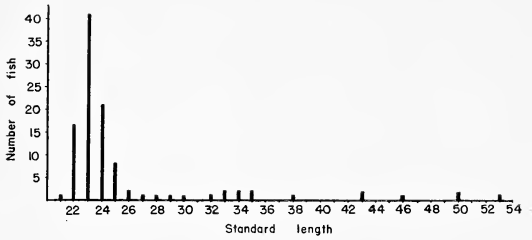

FIG. 7. Collection of *Acanthurus triostegus triostegus* from tide pools of the outer reef flat, Onotoa Atoll, Gilbert Islands, August 21, 1951. Sample size, 108. Nine specimens 21–25 mm. in standard length are transforming from the acronurus to the juvenile stage; the rest are juveniles. Time of full moon, Aug. 16.

males) examined from September to November, 11.8 per cent were running ripe males; 23 per cent of 2,419 adult manini (an estimated two-thirds of which were males) examined from February to June were running ripe males. No variation in degree of ripeness was apparent within the period of a single month. It should be emphasized, however, that no sharp dividing line exists between the condition of a running ripe male and one that is not quite running ripe, and these data tend to be subjective in this regard.

Ripe females are more easily distinguished. Fertilizable eggs of female manini are about 0.7 mm. in diameter, prefectly transparent, and are released when the abdomen is only slightly squeezed. The data on ripe females in terms of the lunar month are summarized in Table 6. As may be seen in this table, the number of fish examined on the different days ranged from 9 to 252. This variability is entirely due to variation in the catches. Also there is no regular sequence in time when the catches were examined. Scheduled sampling was not possible largely because of the great dependence of trap fishing on hydrographic conditions. In addition to being impeded by rough seas, trap fishermen are restricted by turbid water (traps are not found by surface markers but by observing through a glass-bottom box). Although the fishermen ordinarily tend their traps twice a week, they may be held in port several weeks by dirty water. A successful sampling day was also contingent on being at Kewalo Basin when the catches were unloaded. Frequently the fishermen came in unexpectedly early and their fish were promptly taken to market. Market fish were not sampled because catches of previous days may accumulate and the date when fish are caught is usually not available.

A total of 43 running ripe females were found. Thirty-nine of these were taken from 12 days before to 2 days after the full moon and only 4 from the remaining half of the lunar month. A total of 2,552 adult manini were examined in the former period, however, and only 1,311 in the latter; therefore a correction is necessary for this discrepancy in sample size. A corrected figure of 7.8 ripe females instead of 4 is the proper number to compare with 39. Nevertheless, it still remains obvious that a significantly greater number of ripe females, and hence probably greater spawning, occurs before and shortly after full moon than before and shortly after new moon. Since at least a few acronuri of all sizes (see section on transformation) enter tide pools at all times during the month and not totally in one portion thereof, some spawning might be expected throughout the month.

One sample of adult manini was examined on July 29, 1955. There were 7 running ripe female fish among the 57 manini comprising the sample. Full moon occurred on August 3.

It is not known whether spawning by the same fish takes place every month. There is evidence, however, that individual fish spawn more than once a season. The long season in itself suggests repeated spawning. If large ripe females were found at the start and progressively smaller ones throughout the rest of the season, a long spawning season might be indicated with each individual spawning only once, but no obvious trend in size of the 43 ripe females was apparent. The first ripe female of the season, which was found December 1, measured 138 mm. in standard length. The last (July 21) was also large, 140 mm. The shortest found were 106 mm. (March 13) and 101 mm. (July 14). More convincing is the failure to see any completely spent ovaries in fish during the spawning season and the observation of spent and regressing ovaries in all of the females at the end of the season. The strongest evidence concerns the finding in ripe females of a second mode of egg size

TABLE 6

RESULTS OF SAMPLING FOR RIPE FEMALE *Acanthurus triostegus sandvicensis* DURING THE SPAWNING SEASON

DATE	DAYS TO NEAREST FULL MOON		NO. OF FISH EXAMINED	NO. OF RIPE FEMALES
	Before	After		
Jun. 19, 1953	8		40	1
21	6		9	1
Jul. 14	12		114	1
17	9		45	0
21	5		14	1
Dec. 1		11	141	1
8	12		126	1
22		2	139	0
29		9	96	0
Jan. 8, 1954	11		149	1
12	7		21	1
24		5	26	0
Feb. 5	12		30	0
9	8		30	0
12	5		41	1
Mar. 2		13	31	0
12	7		144	6
30		11	44	0
Apr. 2		13	87	0
6	12		198	0
9	9		121	0
13	5		111	0
16	2		193	7
20		2	132	6
23		5	76	0
27		9	151	0
May 1		13	88	0
6	11		83	1
11	6		226	3
14	3		149	2
18		1	18	0
21		4	204	1
25		8	159	0
28		11	103	2
Jun. 11	5		42	2
18		2	97	0
22		6	29	0
25		9	49	0
Jul. 2		14	27	0
9	7		28	0
16	0	0	252	4

about half the size of the ripe egg mode, coupled with the knowledge that this mode is not retained in the ovary through the summer months. This mode of intermediate-size eggs appears to be a persistent unit within the ovary of all mature female manini during and 1–2 months before the spawning season, suggesting that it constitutes a static mass of eggs from which modes of ripe eggs may develop periodically. It is not known whether this mass is built up constantly or at short intervals from the huge reserve of minute primordial eggs which is present in the ovary of every adult female regardless of the time of year (and is here not considered as a mode of egg size).

The procedure for the determination of egg diameters was as follows: Tiny sections were snipped from various parts of an ovary (which was previously preserved in 8 per cent formaldehyde solution) and placed in water in a Syra-

cuse watch glass; the eggs were teased from the ovarian tissue with dissecting needles; the egg diameters were then measured with an ocular micrometer at × 24. Many of the eggs were oblong, probably because of unequal pressure of adjacent eggs at the time of preservation. Instead of measuring the greatest or least diameter, the eggs were moved into position by moving, but not turning, the watch glass on the micrometer image which remained fixed in a horizontal position. This method reduces the possibility of bias but has the disadvantage of increasing the spread of modal groups on graphs of egg diameter measurements.

Graphs of the egg diameters of ovaries from 9 adult female manini are shown in Figure 8. These graphs do not show any definite sequence.

Graph *C*, of a 15 mm. ovary from a female taken on January 2, for example, portrays the egg diameter pattern of an immature but maturing ovary. No graphs were made of egg diameters of ovaries from adult fish taken in August because the fish have only primordial eggs about 1 to 3 micrometer units (.035 to .105 mm.) in diameter except for those in which larger eggs are being resorbed. The relative size of the group of primordial eggs was estimated only for the ovary graphically illustrated in *A*.

Except for the immature gonad of *C*, all of the ovaries display a mode of egg size centered on about 10 to 12 micrometer units in diameter. This prompted the examination of samples of eggs from 54 ovaries taken from female fish throughout the year (more, however, from mature females during the spawning season). Sufficient eggs from each ovary were measured to determine the presence of obvious modal groups. A definite mode at from 9 to 12 micrometer units in egg diameter occurred in 46 of the ovaries, 15 to 35 mm. in length, from fish caught from September 15 to July 21. The median of this mode of 38 of these fish appears to lie between 10 and 12 micrometer units. In the ovaries of 8 fish, the median lies between about 9 and 10 units. One of these fish is the only running ripe female of the 54 examined. The remaining eight fish lack an intermediate-size mode; all of these have small gonads. No specimens were found among the 54 females with a group of eggs which have an average diameter greater than 12 units but less than the 20 to 21 unit average size of ripe eggs. Also, when checking for ripe females among the 3,863 adult manini of Table 6, the eggs pressed from the body cavity of few, if any, of these were of a size between that of the usual mode and the ripe egg mode. It is expected that such a size would be extruded with moderate pressure on the abdomen of the fish, since eggs of about 10 micrometer units (0.35 mm.) are frequently forced out. Eggs as large or nearly as large as completely ripe eggs, but in which small opaque white regions were visible, were seen almost as often as the ripe, perfectly transparent eggs. These can not be fertilized, and females containing them were not considered among the ripe fish previously discussed. The failure to find a mode of eggs intermediate in size between about 10 and 20 micrometer units suggests that eggs maturing from the former modal group (the eggs of which are opaque) do so rapidly. Perhaps the enlargement is essentially a process of hydration.

In view of the finding of so few female manini with fertilizable eggs during the season, it is further believed that the ripe eggs are not retained very long in the ovary. Admittedly a change in behavior of ripe females might influence the frequency with which they enter traps (a possible cessation of feeding, however, would not seem to affect the rate of entry, for the traps, as mentioned, are unbaited). Also, confinement in the traps might affect the maturation of the eggs.

If, however, it is assumed that ripe eggs are held within a female no longer than 1 day on the average, and 43 ripe female fish is the number that would be present in truly random samples of the population equal in size to the ones taken, then the small number of ripe females actually constitutes an indication that every adult female spawns once each lunar month. Since the lunar month is 29.53 days, only about one-thirtieth of the females sampled from the population during the spawning season would be ripe. As mentioned, 3,863 adult manini were examined during the 1953–54 season, an estimated one-third of which, or 1,288, were females. One-thirtieth of 1,288 is 43, precisely the number of ripe females which were found.

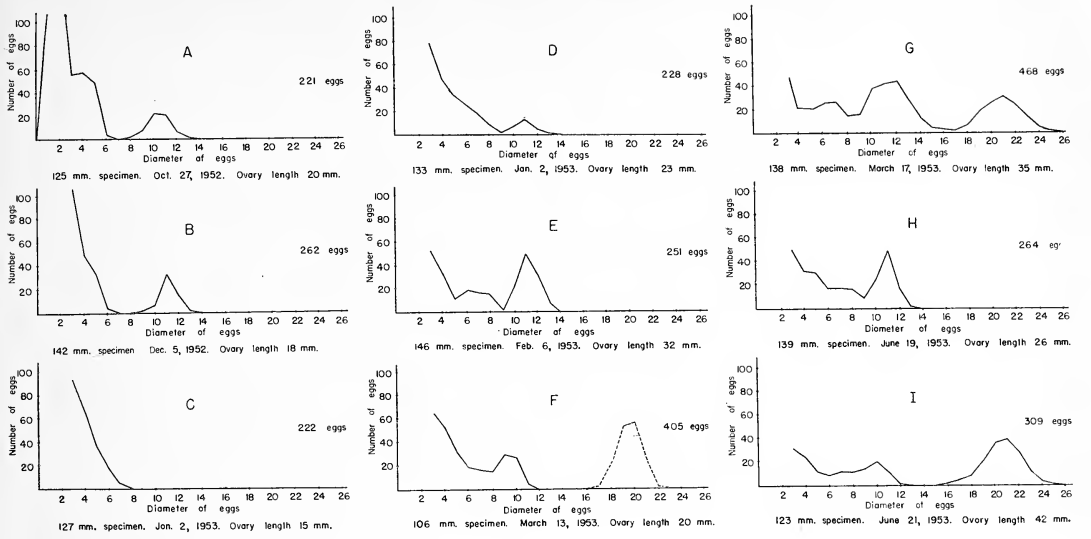

FIG. 8. Egg diameters of *Acanthurus triostegus sandvicensis* plotted as units of an ocular micrometer. Scale: 1 unit = .035 mm. Except for *A*, where the number of eggs of 1 and 2 micrometer units were estimated at 1,575 and 627, respectively, no eggs less than 3 micrometer units were measured.

Spawning

The spawning of *A. triostegus sandvicensis* was never witnessed, in spite of considerable observation both at night and during the day and at various times of the month. On June 12, 1957 (full moon) *A. triostegus triostegus* was observed to spawn at the atoll of Tikahau in the Tuamotu Archipelago at dusk (5:30 P.M.). It is believed that the failure to see the Hawaiian manini spawn was due to the lack of effort at dusk. The following account of the reproduction of the Tuamotu manini is probably similar to that for the Hawaiian subspecies.

Several hundred spawning *A. triostegus triostegus* were observed in the pass at a depth of about 25 ft. Many of the fish displayed a marked color change. The black bars on the side of the body were much broader (but the added width on either side of each bar was not as intense a black as the center); the median fins were dark, almost black, except for the middle of the caudal which remained pale; the dark median band on the forehead was prominent. Five fish of this color pattern were speared (when pursued, an individual dark-colored manini resumed normal coloration within about 10 sec.); all 5 were ripe males. As many as 4 or 5 of these more melanistic fish were repeatedly observed chasing single fish which were unchanged in color pattern. Two of the normally colored manini were speared. One was a running ripe female and the other a female with opaque eggs which were squeezed from the body only with considerable pressure; thus not all females in the spawning aggregation are capable of reproduction at the same time, which is in keeping with the finding of running ripe female manini in Hawaii along with fish with maturing ova on many different days of the lunar month (Table 6). Actual spawning took place among small groups of fish within the large school which became increasingly active and suddenly darted upward about 8 ft. above the rest. Eggs and sperm were released at the apex of this movement. Swimming was more rapid as the apex was approached. The fish dispersed as they swam back down to mingle with the school. At times two or more small groups joined together in the first few feet of the upward movement, resulting in a dozen or more fish in a compact mass at the top. The attempts to spear individual fish broke up the one large aggregation into several lesser ones in which spawning took place infrequently.

Two other surgeonfishes, *Ctenochaetus striatus* (Quoy and Gaimard) and *Zebrasoma scopas* (Cuvier), were observed to spawn in the Society Islands. Like the manini, they exhibited the sudden upward rush prior to spawning. Possibly the release of eggs and sperm is facilitated by the expansion of the airbladder from the decreasing pressure caused by the upward swimming movement. Like the manini in the pass at Tikahau, both of these surgeonfishes were spawning in a region of strong current to the open sea.

Size and Age at Maturity

The smallest running ripe female seen by me was 101 mm. in standard length. The smallest running ripe male was 97 mm. in standard length. These are probably near the minimum lengths for mature manini around Oahu.

Ten manini were reared in a large concrete tank of the Hawaii Marine Laboratory at Coconut Island from a size of 25 to 27 mm. in standard length beginning on March 17, 1953 (see detailed discussion in section on growth). Two fish of this group, an 89.5 mm. male and a 99 mm. female were killed for gonad study on July 24, 1953. The female had an immature gonad, clear gray in color, and only 5 mm. in length. The ova were minute, only 0.015 to 0.03 mm. in diameter. The male was detected because it was possible to strip a small amount of milt from it, although considerable pressure on the abdomen was necessary. The sperm, however, were not motile. Its testis was slender and 6 mm. long. Subsequent examination of the gonads of the remaining 8 captive manini was not made because of arrested growth of these fish following inadvertent destruction of the algal food supply when seining the tank.

There appears to be considerable variability in the size at maturity. This variability is apparent when the 101 mm. ripe female manini is contrasted with the 127 mm. immature specimen whose egg diameters are graphically illustrated in Figure 8, *C*.

It is doubtful that any female manini spawn during the season in which they first arrived as acronuri in tide pools. Even if the 99 mm. female, which was killed on July 24 following its growth in captivity from a small juvenile on March 17, had been among the first few arrivals to shallow water of the season (middle February), another month of growth and gonad development would hardly seem sufficient to bring a tiny immature ovary such as that seen in this specimen on July 24 to full maturity before the season ended. It also seems unlikely that males will spawn within their first season following recruitment to tide pools.

It seems probable, from a knowledge of growth (see growth section) and the approximate size at maturity, that some manini will spawn in the season following their first sojourn as juveniles in inshore waters. This would be very likely for the first young of the season; the last young of the season would not seem to have sufficient time to develop to sexual maturity before the following spawning season ended. Such a situation would probably increase the variation in the size of the fish at maturity.

Fecundity

Fecundity is defined as the total number of ripe eggs produced by a female in 1 year. It is impossible to ascertain this for fish like the manini which may spawn more than once a year, when the number of spawnings per year is unknown. Therefore only the number of eggs released at one spawning can be determined. This was attempted for only a single manini.

The fish chosen for the egg count was the 123 mm. June 21 specimen, the egg diameters of which are plotted in Figure 8, *I*. This fish had a very large ovary (42 mm. in length) which contained a high percentage of large eggs. These eggs were not completely transparent, and none appeared to have been expelled by the fish. The ovary was vigorously shaken in the vial in which it had been preserved with a minimum of fluid. The agitation released nearly all of the near-ripe eggs from ovarian tissue and placed them in uniform suspension. The contents of the vial were then placed in a graduated cylinder, allowed to settle, and the small amount of excess fluid poured off. A sample of the ovarian mass was drawn off. After its removal, the volume was computed as 26 per cent of the total. All of the large eggs in this sample were counted in successive lots placed in a Petri dish under a binocular dissecting microscope. The sample

contained 10,814 large eggs. The total number of large eggs in this ovary was therefore estimated at 40,000.

DEVELOPMENT

Fertilization of the eggs of the manini was effected artificially, using live fish obtained from trap fishermen. As previously discussed, ripe female fish are detected by the release of perfectly transparent eggs following gentle pressure on the abdomen. The milt of running ripe male manini oozes even more readily from the fish than the eggs of ripe females; however, it was found that eggs could be fertilized with sperm from males in which definite squeezing was necessary to bring forth the milt. Eggs were fertilized both by stripping ripe males and females concurrently into sea water with genital apertures in close proximity and by stripping them separately into different containers and subsequently mixing the contents.

The fertilized eggs are spherical, 0.66 to 0.70 mm. in diameter, and contain a single oil globule which is 0.165 mm. in diameter. If suspended in sea water, the eggs slowly rise to the surface. They exhibit no stickiness and do not adhere to objects or one another, although they often lie in single-layered groups at the surface.

Unfertilized (but fertile) eggs are also less dense than sea water. No difference in diameter of unfertilized and fertilized eggs could be detected.

Developing eggs were placed in large finger bowls, an aerated battery jar, and an aerated 20 gal. aquarium. In all of these containers heavy mortality of the larvae ensued because of settling to the bottom (probably through contact with bacteria there and not to any physical injury). Efforts were made to keep the larvae in suspension by placing a fine-mesh false bottom in a battery jar and locating a bubbling aerator stone beneath a hole at one side and by installing a paddle which was slowly turned by an electric motor. Although these methods reduced the amount of settling, mortality was still high and only a few larvae survived to an age of 5 days or more, when oriented swimming began.

In view of the difficulty of rearing larvae in rigid containers, a new approach was tried for the manini. A fine-mesh bag, 1.2 m. on a side, with cork along the top was floated in the Ala Wai Yacht Basin. Fertilized eggs were placed within and allowed to develop. Approximately the same mortality resulted, however.

Once the manini larvae were capable of oriented swimming, they were maintained as easily in unaerated finger bowls as any other way. At this time the critical factor became the supply of food.

The principal stages in early development from 0 hr. to 5 days 22 hr. are shown in Figures 9–12. The drawings of eggs before hatching were made shortly after placing the eggs in 10 per cent acetic acid, a treatment which makes the blastodisc opaque white and the cleavage pattern more visible. The ages given are based on an average development temperature of 24° C. During development the temperature was 24° C. ± about 1°.

Although temperature control was not sufficiently precise to permit an assay of the change of rate of development with changing temperature, it was obvious from the rearing of one batch of eggs at 26° C. ± 1°, that temperature has a marked effect on the rate. The stage attained at 28 hr. 40 min. at 24° C. was reached in about 22 hr. 30 min. at 26° C. The 42-hr. stage at 24° C. was reached in about 32 hr. at 26° C.

No attempt was made to determine the temperature limits within which normal development of the manini is possible. Due to proximity of a light bulb, the temperature of one finger bowl in which 37-hr. larvae were developing was inadvertently raised in a short time to 29.3° C. None of the larvae died at this time.

The blastodisc of the fertilized egg is 0.4 mm. long. One hour after fertilization the first cleavage becomes apparent. At the end of the second hour 8 cells are present, and after 4 hr. about 55 cells can be counted in the blastodisc.

At the age of 6 hr. gastrulation is under way. Epiboly is evident from the thin layer with a wavy edge which is extending downward over the yolk. The cells are very small and are not shown in the drawing of this and subsequent stages.

At 14 hr. the primitive streak is apparent and the cephalic region of the embryo well developed. By about 18 hr. epiboly is complete, and

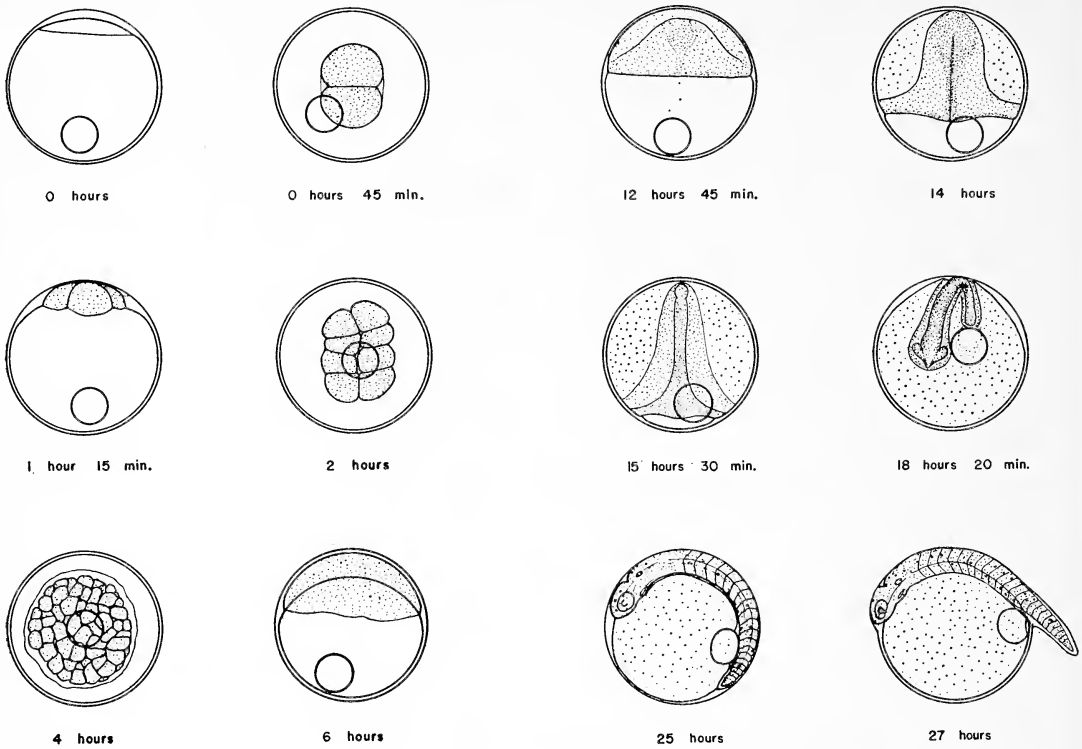

FIG. 9. Developing eggs of *Acanthurus triostegus sandvicensis*. Egg diameter, 0.67 mm.

the yolk plug is visible as a small clear area near the oil globule.

By 15 hr. 30 min. the body of the embryo is beginning to take form and elongate over the yolk. At 18 hr. 20 min. 9 somites can be counted and the optic vesicles are prominent. At 21 hr. 45 min. 12 somites are present. At 25 hr. 19 or 20 somites are visible; the lens of the eye is just starting to form; the auditory vesicle is present and the statoliths are just forming; 24 tiny melanophores can be seen in lateral view on the body; twitching movements are common; the heart contains blood although it has not yet started to beat.

Hatching occurs at the age of about 26 hr. At 27 hr. the larva is nearly 1.7 mm. in length and has 22 somites; the heart is still quiescent. At 31 hr. the heart was observed to beat; occasional short random swimming movements occur by rapid vibration of the posterior half of the body.

At the age of 42 hr. the amount of yolk is reduced to about half of what is present in the 31-hr. larva. As the yolk is used up, the larvae show a progressive tendency to sink. Larvae of 39 hr. still float head down at the surface, but 42.5-hr. fish have begun to settle. The rate of settling of 1 larva at this age was measured at 1.2 cm. per min. The average rate of 3 44.5-hr. larvae was 1.67 cm. per min., and the average rate of 4 47-hr. larvae was 1.88 cm. per min. One 71-hr. larva sank at the rate of 8.2 cm. per min.

At 42.5 hr. some larvae were already settling out at the bottom of the aquarium. Most, however, maintained their level by swimming movements. 300 such movements were observed in an aquarium which contained several hundred larvae. Of these movements, 227 resulted in the larvae being in a higher position in the tank; the rest were sideways or downward. Movements which consisted only of a twitch were not

counted. The ability to overcome settling is more efficient than 227 movements with an upward component out of 300 would indicate. Since the head is directed downward, swimming is initiated in this direction. In most cases the fish soon turn sharply and swim upward. If the interval of movement is short, there may be insufficient time to end up higher than the starting position, but usually the fish is not significantly lower. The interval between movements is highly variable, but it averages about 1 min. The distance traveled by the larvae per movement is usually less than 40 mm. One, however, stopped 110 mm. above its starting position.

In addition to geotaxic responses, swimming movements were made to avoid contact with an approaching object. This was first observed in 42-hr. larvae; however, it may be operative several hours earlier. The eyes do not seem sufficiently well developed to be functional at this early age, and a glass rod is detected as easily as an opaque one; thus vision would not seem to be the sense responsible for perception of an approaching object. Before such an object touches a larva, and sometimes when it is as far as 2 or 3 cm. away, a fleeing movement is initiated. A second stimulus soon after the flight reaction will usually result in a second swimming movement. Contact with the bottom due to slow settling usually will not result in a swimming movement. Regular movements occur at about the same rate when the fish are on the bottom. They may enable a larva to become suspended again, but usually only for a short time.

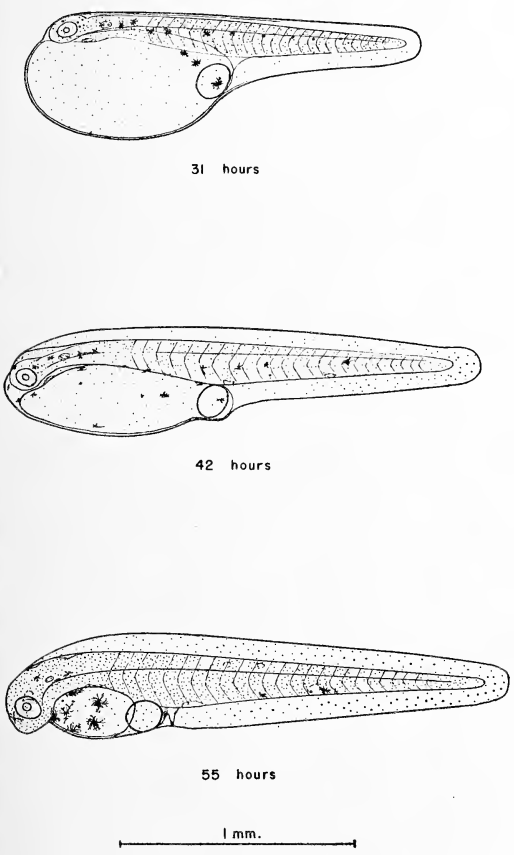

FIG. 10. Early larval stages of *Acanthurus triostegus sandvicensis*.

Areas of white pigment are beginning to form on the ventral part of the seventh and fifteenth somites of the 42-hr. larva. These are large and conspicuous in the 54-hr. larva, and lesser white areas may be seen on the ventral part of the body anterior to the seventh somite and on the head. At this stage the intestine has just formed and the yolk mass is small. The melanophores over the yolk are large and dendritic.

Figure 11 consists of microphotographs of living 75-hr. and 4-day 1-hr. larvae with the light transmitted through the little fish. The dorsal fin fold is a prominent feature at 75 hr. (it was first noticed in the 66-hr. larva), and the pectoral fins are developing. Dark pigment around the eye is evident. The 4-day 1-hr. larva was observed to sink less rapidly than prior stages. One larva of this age sank 2.5 cm. per min. and another less than 1 cm. per min. The 4-day 12-hr. larva remained suspended head down in the water, thus indicating that the air bladder was functional. The jaws were observed to move in the 4-day 5-hr. larva (Fig. 12).

Although still tending to float head downward, the 5-day larva is capable of normal oriented swimming. The pectoral fins can be fluttered rapidly, and the eyes move. The yolk is completely gone and the oil globule half resorbed. By 5 days 12 hr., the 3 individuals which survived to this age appeared to be feeding by short darting movements. Material from a culture of marine ciliates was added to the finger bowl in which these 3 larvae were kept. One

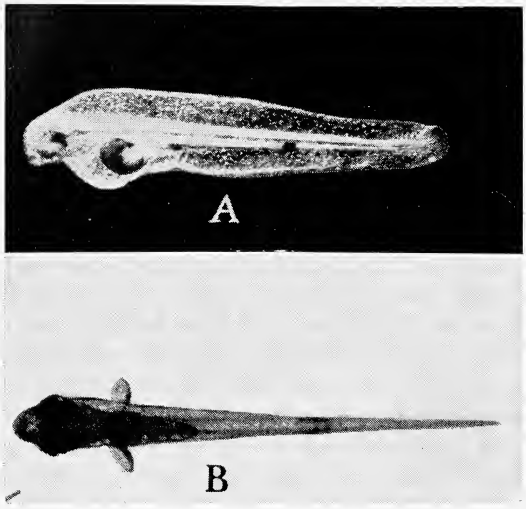

FIG. 11. Microphotographs of larval *Acanthurus triostegus sandvicensis*. *A*, Side view of 75-hr. larva; length 2.3 mm. *B*, Four-day 1-hr. larva in top view; length, 2.5 mm.

died after 5 days 17 hr. of development. Food was present in the intestine of this specimen. The second member of this trio was observed to be dying at the age of 5 days 22 hr. It was removed from the finger bowl for the lower drawing of Figure 12. As may be seen in this drawing, no trace of the oil globule remains, the intestine is convoluted, the liver is prominent, and the gall bladder is visible. The two large white areas on the body have disappeared. The total length is nearly 2.7 mm. The last larva survived to the age of 6 days 12 hr. It grew very little in the last 24 hr., presumably because of insufficient or inadequate food.

Three of the 11 acanthurid lavae from the POFI plankton collections (see p. 216) were identified as manini by dorsal and anal fin-ray counts. They are 6.6–7.0 mm. in total length. Figure 13 is a drawing of the 6.6 mm. specimen (standard length 5.3 mm.). The teeth are not visible without opening the jaws. They are simple canines. The total length of the anterior upper teeth is contained 3.7 times in the diameter of the pupil of the eye.

Specimens smaller than this one could not be identified by ray counts, for the soft rays are not fully formed. A 4.2 mm. specimen could not be positively identified at this time to genus, for only the first three dorsal spines are sufficiently developed to distinguish them from soft rays; however this specimen is about intermediate in structure to the 5-day 22-hr. larva and the 6.6 mm. larva (though is closer to the latter). Its body depth is contained 1.8 times in the total length, and the relative length of the second dorsal, second anal, and pelvic spines is about two-thirds as great as that of the 6.6 mm. larva. The caudal fin is about half formed, the urostyle extending to the posterior part of the incipient fin.

A 4.3 mm. specimen was the only acanthurid found in the POFI larval fish collections which were taken with a 6-ft. modified Isaacs-Kidd trawl, except for an 18 mm. *Zebrasoma veliferum* (Randall, 1955*c*: fig. 3). It was captured near the surface off Kahuku, Oahu. Although a little longer than the specimen just mentioned, it is in a slightly earlier stage of development and is probably a different species. If a large series of specimens were available instead of just a few it might be possible to identify the various stages of the manini to the size where fin-ray counts alone can provide definite identification.

No postlarval specimens of *Acanthurus* greater than 8.7 mm. in length but smaller than the acronurus form were found in any of the POFI collections or museum collections. As previously discussed, specimens larger than about 9 mm.

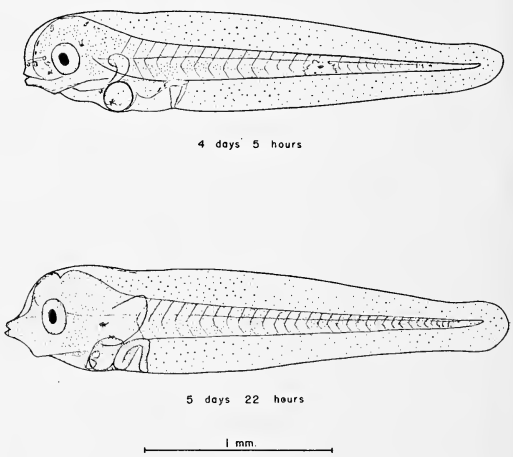

FIG. 12. Larval stages of *Acanthurus triostegus sandvicensis*.

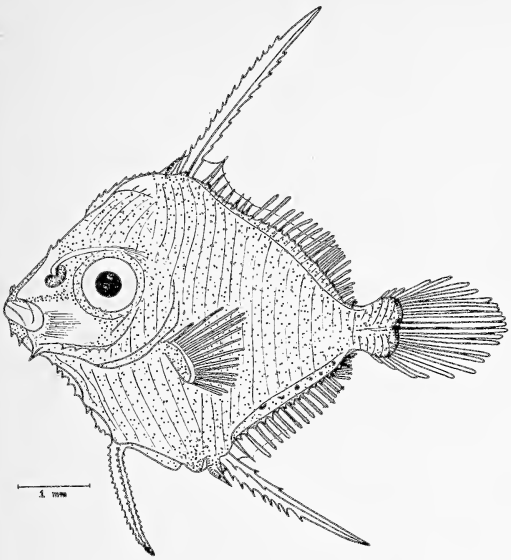

FIG. 13. Postlarval *Acanthurus triostegus sandvicensis* taken in a 1 m. plankton net at a depth of 50 m. at 22° 38′ N., 157° 11′ W.

in length probably elude a meter plankton net. The presence of the 18 mm. *Zebrasoma veliferum* in the collections from the 6-ft. trawl suggests that this would be a better means of catching larger larval acanthurids. The failure to take more acanthurids in the trawl is probably due to the great distance from land of most of the trawl tows.

The only records of the early stages of *Acanthurus* found in the literature are two postlarval *A. coeruleus* identified by Lütken (1880: pl. 5) and an unidentified 7 mm. postlarval *Acanthurus* in Weber (1913: fig. 70). Spartà (1928) reported on a long, ribbon-like, transparent, pelagic egg mass of an unknown teleost fish from the Mediterranean. The early developmental stages which he succeeded in rearing from this egg mass are remarkably similar to those of the manini. Spartà concluded that the eggs were from a species as yet unrecorded from the Mediterranean.

TRANSFORMATION

The late postlarval form of the genus *Acanthurus* is characteristic in morphology, yet identifiable to family Acanthuridae by the presence of the caudal spine and a diagnostic number of fin rays. Originally this stage was placed in a genus by itself, *Acronurus*. The name acronurus has persisted as a common name for this stage, reminiscent of the leptocephalus of eels.

Acronuri are commonly taken at night-light stations. Sixty-two manini acronuri and many of other species collected at night lights and by night-light traps offshore in the vicinity of the Hawaiian, Line, and Phoenix islands were examined. No specimens in night-light collections were found which were smaller than the acronurus stage. It is inferred, therefore, that a positive phototaxis develops in the acronurus. The lack of food material in the gut of night-light specimens (see p. 223) indicates that the presence of numerous small planktonic animals around a light at night is not the attractant. Once transformation to the juvenile stage has begun, the positive phototaxis disappears.

Figure 14 is a photograph of a live specimen of the manini acronurus taken shortly after its arrival in a tide pool. The characteristic transparent scaleless body with silvery abdomen and head (except snout and nape), disk-like form, and vertical striae on the body are apparent. The vertical bars are just beginning to form.

The acronurus comes into inshore regions

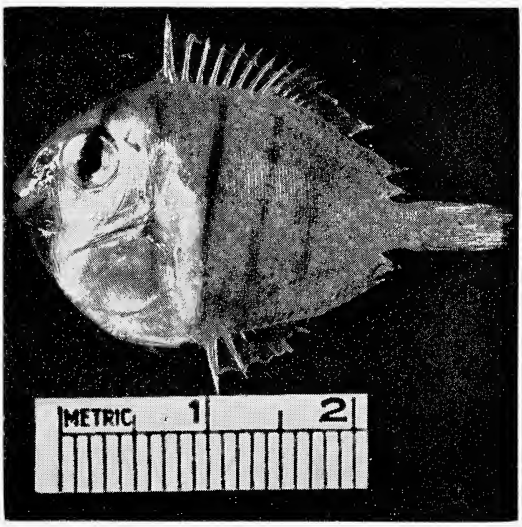

FIG. 14. The acronurus of *Acanthurus triostegus sandvicensis*. Captured at dawn in a tide pool at Diamond Head, Oahu, and photographed alive.

only at night. New arrivals to inshore areas have been collected all through the night, some as early as 9 P.M. and others just before dawn. Most of the night collecting was done at low tide. It is not known whether the influx of acronuri is greater at one phase of the tide than another.

On two occasions before midnight at low tide in ankle-deep water along the shore of the Ala Wai Yacht Basin near the entrance to the Ala Wai Canal, manini acronuri were observed just coming into the area from deeper water. They did not passively float into the shallow zone but swam in rapidly. One crossed several times through the beam of a head lamp before it was caught. If it is assumed that these fish were in deep water beyond the breaker zone before nightfall, then they must have actively swum into the harbor area and not been carried in by any tidal currents. Prior to low tide, tidal currents would be flowing out of the yacht basin and not into it. This is contrary to the belief of Breder (1949*a*: 296) that acronuri of *Acanthurus hepatus* (= *A. chirurgus*) are carried into shallow water by "vagaries of current."

Breder reported observing transforming specimens of *A. chirurgus* at sizes from 23 to 29 mm., and found juveniles from 10 to 20 mm. in length in tide pools at Bimini. He inferred that late postlarval surgeonfish reach a certain size in the plankton at which transformation is possible but continue to grow. The size at transformation is dependent on the size of the acronurus when it reaches shallow water. Breder's explanation of the cause of this variability in transformation size is plausible, although a range of at least 10 to 29 mm. for one species seems high.

From April 11 to October 4, 1953, a total of 175 manini were found in shallow water on Oahu in their first day of transformation to the juvenile stage. Their standard lengths (measured to nearest 0.5 mm.) ranged from 22 to 29.5 mm. Even this would seem, a priori, to be more variation in length than would be expected from mere growth variation alone in the pelagic habitat. A small amount of this variability in Hawaii is due to the change in temperature at which development occurs during the season (Fig. 16 and discussion below), but considerable variation can be seen in the transformation size of acronuri taken within the period of a single month, and therefore cannot be attributed to seasonal temperature differences.

The fluctuation in abundance of incoming young manini has provided an opportunity to test Breder's hypothesis. If the variation in size at transformation were entirely due to normal variation in growth, then no difference should be apparent in the size of manini which are transforming during the time of the month when a big influx is occurring and the period when the recruitment to inshore areas is minimal. If, however, more extremes in size were found when the recruitment is at a minimum, it could be assumed that growth of the manini occurs in the plankton after transformation is possible and that members of a modal group which arrive inshore and transform earlier or later than the majority of the group will be smaller and larger, respectively.

In Figure 15 the lengths of the 116 transforming manini which were collected within the period 5 days before to 5 days after peak tide-pool recruitment (taken as 2 days before the time of new moon; see p. 234 and Fig. 6) are compared to the lengths of the remaining manini caught outside this period. Clearly, a higher percentage of extremes in length at transformation occur during the part of the month when the number of acronuri entering shallow water to transform is low.

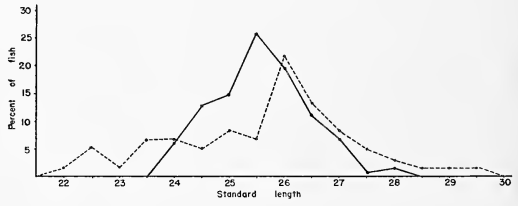

FIG. 15. Size of *Acanthurus triostegus sandvicensis* during the first day of transformation from the acronurus to the juvenile stage. The solid line represents the percent of fish at the designated standard lengths from samples taken 5 days before to 5 days after peak tide pool recruitment (3 days before new moon). The dotted line represents the percent of fish from samples taken during the rest of the lunar month. The solid line is based on a total of 116 fish and the dotted line on 59 fish. Samples include all of the first day transforming manini which were collected from Apr. 11 to Oct. 4, 1953.

If spawning of the manini occurred only during a definite small segment of the month, the dotted curve of Figure 15 would probably be bimodal, one of the modes centered on a low and the other on a high standard length. Since, however, spawning appears to occur throughout the month and merely more prominently in one part than another, most of the young resulting from fertilization at a time of low spawning intensity will come into shoal areas at a more nearly average size during the interval between periods of high tide-pool recruitment and obscure the postulated bimodal effect. The extremes in size of this small group would enter the tide-pool zone at the time of peak recruitment; thus, if the samples were large enough, both curves would extend to the same limits.

The maintenance of populations of manini around small islands such as Johnston Island, the shores of which are constantly swept by a strong current in one direction, would seem to demand some means on the part of the developing pelagic larvae to remain close to land. The presence of small eddy systems around an island might afford the explanation, provided the larvae can stay within such systems. The apparent differentiation of the manini at Johnston Island (Randall, 1956*b*: table 2) and also of *Ctenochaetus strigosus* (Randall, 1955*d*) would seem to rule out the possibility that the Johnston Island populations are derived primarily from fishes which spawn in the Hawaiian Islands proper.

While examining museum specimens of transforming manini from many localities, a definite variation in size with locality was noticed. The standard lengths of the available early transforming museum specimens were measured. These lengths (except those of Hawaiian Islands specimens, already presented graphically) are given in Table 7 with localities and with collection dates when known.

A correlation exists between the size of manini at transformation and the temperature of the water of the locality. The warmest region listed in the table is the East Indies where the mean monthly sea surface temperature may reach 85° F. (29.4° C.) (Hydrographic Office, 225). Here we find the smallest size at transformation, 20–21 mm. Small standard lengths, averaging less than 23.5 mm., are found in other warm areas such as the Palau, Marianas, Gilbert, and Marshall islands (all regions where the mean monthly sea surface temperature exceeds 81° F., or 27.3° C., during the entire year), and southern India in January, and Okinawa in September. Transforming specimens from regions where the temperature is 80° F. (26.6° C.) or less throughout the year or during the month of the date of collection are large, 24 mm. or greater in standard length. These areas include Durban (S. Africa), New South Wales, Ningpo (China), Hawaiian Islands, Mangareva, the Marquesas Islands (in August), and Clarion Island. The large transformation size of the specimens from the Phoenix Islands, where the sea surface temperature exceeds 82° F. (27.8° C.) all year, is an obvious exception to the above. Perhaps the manini population in these islands has differentiated in this respect, although the Phoenix group is not markedly isolated.

In order to preclude the possibility that the different transformation sizes of the different areas are entirely due to genetic factors (reflecting possible races of the manini in all these areas) a comparison was made of the size at transformation of specimens obtained at Oahu in an early cool and a late warm part of the season. Thirty-nine first-day transforming manini were obtained in collections from April 11 to May 8, 1953. The standard lengths of these specimens are plotted as the solid line of Figure 16. The dotted line enclosing the stippled portion of the graph represents the lengths of 38 first-day transforming manini taken from July 7 to October 4, 1953. The average sea surface temperature at Oahu from February to May is 75.7° F. (24.2° C.); the average from July to October is 79.1° F. (26.2° C.), based on average temperatures from 1941 to 1947 presented by Leipper and Anderson (1950). The mean length of the April–May group is 26.256 mm.; the mean length of the July–October group is 25.447 mm. Although the difference in length appears highly significant, a t test was made by the group comparison method (Snedecor, 1948: 80). The resulting t value of 3.11 gives a probability of nearly 0.001 of obtaining a value greater than this; thus it is extremely unlikely that samples as diverse as the above could be

TABLE 7

SIZE OF *Acanthurus triostegus* AT TRANSFORMATION FROM THE POSTLARVAL TO THE JUVENILE STATE

LOCALITY	DATE	NO. SPECIMENS	STANDARD LENGTH (mm.)	
			Range	Mean
Durban, S. Africa	May 8	2	23–25	24
S. India	Jan. 19	1	22.5	22.5
East Indies				
Sumatra	Dec. 19–25	1	21	21
Moluccas	——	10	19–21	20.2
New South Wales	——	3	24–25	24.3
Palau Is.	Aug. 3–6	7	21–23	22.1
Philippine Is.	Jun.	1	23.5	23.5
Okinawa	Sep. 6–8	2	22	22
S. Japan (30.4° N.)	——	2	21–23	22
Ningpo, China (29.5° N.)	——	5	24–26	24.9
Mariana Is.				
Guam	Jun. 28	3	22–24	22.7
	Jul. 24	7	20.5–23	21.8
	Nov. 25	2	21.5–23	21.25
Saipan	Jul. 9–14	1	22	22
Rota	Nov. 11–13	16	21.5–24	22.5
Marshall Is.				
Bikini	Apr. 1	1	23.5	23.5
	Aug. 17–18	2	22–22.5	22.25
Eniwetok	May 20	2	23–23.5	23.25
Kwajalein	Jun. 24	7	22–24	22.7
	Sep. 1	3	22–24	22
Onotoa, Gilbert Is.	Aug. 21	9	21–25	23.2
Samoa Is.				
Tutuila	Jun. 3	1	22	22
Rose	Jun. 11–14	1	24	24
Swains	May 3–9	1	25	25
Phoenix Is.				
Canton	Apr. 15–28	3	25–26.5	25.8
	May 13	3	25–27	25.8
Enderbury	May 15–19	7	25–27	25.3
Hull	Jul. 7–17	9	23–25.5	24.1
Howland I.	Sep. 24	8	23.5–26	24.3
Line Is.				
Palmyra	Jan. 18	1	23.5	23.5
Fanning	Aug.	1	24	24
Wake I.	Jun. 9	2	23.5–24	23.75
Marcus I.	Aug.	4	25–26.5	25.6
Marquesas Is.	Feb. 3	1	26	26
	Aug.	2	26–26.5	26.25
Makatea, Tuamotus	Feb. 13	3	23.5–25	24.3
	Mar. 15	8	23–25.5	24.4
Mangareva	Feb. 3	7	24–25	24.7
Tahiti	Feb.	1	26.5	26.5
	Apr. 28	1	23	23
	Jun. 16	11	22.5–26	24.2
	Jul. 8	2	23.5–24	23.75
	Aug. 12	4	22.5–24	23.4
	Aug. 28	5	23–25.5	24.4
	Oct. 4	3	25–27	25.7
	Dec. 30	17	22.5–26.5	24.5
Clarion I., Mexico	——	1	25	25

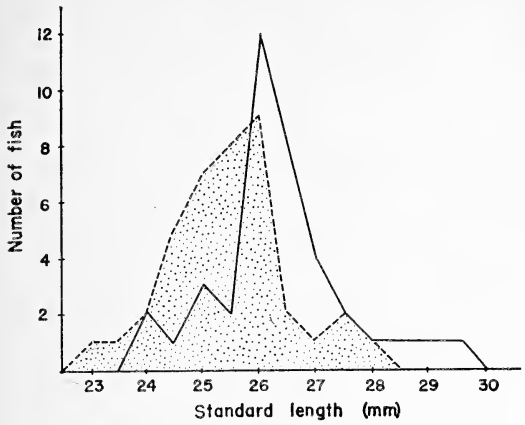

FIG. 16. Size of *Acanthurus triostegus sandvicensis* from Oahu during the first day of transformation from the acronurus to the juvenile stage. The solid line represents all of the specimens collected from Apr. 11 to May 8, 1953; the dotted line indicates those collected from Jul. 7 to Oct. 4, 1953.

drawn by chance from a population in which the transformation length was the same throughout the season. It is therefore concluded that a relationship as indicated above exists between the size of transformation of the manini and the temperature of the water.

Breder (1949*a*) stated that the complete transformation of *Acanthurus chirurgus* occurred in a period of about 48 hr. He did not, however, define the morphological state that constitutes complete transformation. In the manini, adult coloration is nearly acquired after about 48 hr., but other major changes are less than half completed after this length of time. Admittedly it is difficult to define a precise stage at which larval characteristics have completely disappeared and miniature adult structure is assumed. Probably the most convenient criterion is the stage at which the scales have completely formed. Drawings of developing scales have been made by Poey (1875: pl. 3) for the West Indian species, *Acronurus caeruleatus* (= *Acanthurus coeruleus*) and *Acronurus nigriculus* (= *Acanthurus bahianus*). The first evidence of the formation of the scales is the appearance of scattered thornlike outgrowths which project upward as well as posteriorly from the narrow, vertical, fleshy ridges of the body (these spines do not occur on the anterior half of the body). The spines are present on manini acronuri caught offshore at a night light, but they can be seen on these specimens only with the aid of a microscope. They enlarge and become visible (when wet) with the naked eye on the majority of first-day transforming individuals as early as 7:00 A.M. Each such spine on later stages was found to be a central stout ctenius of a single developing scale; the majority of scales, however, do not possess these. As scale development proceeds, the large ctenii flatten and become overlaid with epidermis. When this occurs, scale development is essentially complete as are other major changes of the transformation process. Scale development normally requires 4-5 days. In an aquarium the whole process seems delayed, and about 6 days are necessary.

Figure 17 shows transforming manini on the first, second, third, and fourth to fifth days. The second-day and third-day stages were identified with assurance by comparison with specimens recovered in tide pools following fin clipping on the first day of transformation. No older marked specimens were recovered at the stage when scale structure is just complete, and the time this required had to be inferred from the percentage of specimens in the different stages collected in the weekly poison stations of the Diamond Head tide pool of Figure 4.

FIG. 17. Transformation of *Acanthurus triostegus sandvicensis* from the acronurus to the juvenile stage. Upper left, first day; upper right, second day; lower left, third day; lower right, fourth or fifth day.

The vertical dark bars which are so characteristic of the manini are absent from the majority of night-light specimens. They are faintly visible on a few such specimens, however. Manini caught in tide pools during the same night when they came in usually possess traces of the dark bars, but some, presumably very recent arrivals, totally lack these markings. One of the two previously mentioned specimens which were observed just entering shallow water from deeper areas of the Ala Wai Yacht Basin had traces of the bars, and the other lacked them. The bars are not dark on any of the specimens collected at night. During daylight of the first day of transformation the bars become intensely dark brown. This suggests that sunlight might accelerate or perhaps even be necessary for the darkening. In a review on the biochemistry of the production of melanin, Lerner and Fitzpatrick (1950: 119) pointed out that ultraviolet irradiation appears to be concerned with melanin formation in at least four different ways, all of which tend to increase pigmentation.

An experiment was designed to determine whether any changes occurred in the transformation process when light is excluded. Two transparent specimens which displayed no evidence of dark vertical bars on the body were taken at midnight. These were placed in a battery jar containing 2½ gal. of aerated fresh sea water. The jar was covered with a box which, in turn, was covered with a heavy black cloth. Three other transparent specimens taken at the same time were placed in a aquarium of about the same capacity which was not darkened. The battery jar was uncovered 12 hr. later. The transformation of the two specimens had barely started. The stage which was reached was about comparable to transforming fish taken shortly after dawn. The bars on the side were barely discernible and the ctenii of the developing scales on the posterior half of the body were just visible. One of the fish was on its side, dying. It was removed, and the jar was again darkened. Eight hours later the second specimen was found nearly dead. The bars were possibly a little darker; the transparency of the body was largely replaced by opaque white, an abnormal color alteration. The three aquarium specimens completed their transformation. The results suggest that light is essential to normal transformation. To be conclusive, however, the experiment should be repeated several times. If light were conclusively demonstrated to be essential to the metamorphosis of the manini, the mechanism by which it exerts its effect would still not be known. It might act directly on the tissues, or by way of the visual sense, or both.

During the first day the transparency of the body is gradually lost. By the end of the day the dark brown bars on one side of the body cannot be seen through the body from the other side as they may be on specimens such as the one in Figure 14. The bright silver color on the abdomen and head is slightly dulled by the end of the day due to the development of melanophores external to the silver layer. The iridocytes causing the silver sheen on the abdomen are present in the peritoneum. On the gill cover they occur in a layer on the underside of the opercular bones. They are found on the surface of the cleithrum at the edge of the gill opening. No silver color is present dorsal to the eye. Instead there is a broad black band which covers the brain. This is found beneath the dorsal bones of the head. By the third day both the silver color and the black band on the head are nearly imperceptible. They are, like the rest of the body except the region of the dark bars, white with numerous, close-set, small flecks of dark brown. The olivaceous cast of the body as seen on juvenile and adult manini is not conspicuous until about the fourth or fifth day of transformation, probably because of slow development of yellow chromatophores.

The second dorsal and second anal spines of the acronurus stage are longer and stouter than the other spines of these fins (Fig. 14). If stuck by either of these spines or by the pelvic spines, a stinging sensation almost comparable in intensity to a bee sting is felt. It is believed that these same spines, very elongate in the 6.6 mm. manini, are venomous in earlier stages. The poisonous nature of the spines appears to be a larval adaptation, for it is lost by the third day of transformation. A diminution in the relative length of the second dorsal and second anal spines may be seen in the series of transforming specimens of Figure 17. The relative change in length of these spines continues until, in late

juveniles and adults, the third dorsal and third anal spines are much longer than the second dorsal and second anal spines, respectively. The latter, however, remain thicker. All of the acronurus spines are T-shaped in cross-section; all are solid. The nature of the venom apparatus is unknown. The T-shape of the spines persists into the juvenile stage.

One of the most striking changes during transformation is the alteration of the configuration of the head. This consists primarily of an increase in the length of the snout, resulting in the mouth being in a more ventral position. The rostral prolongation may be seen in Figures 14 and 17. The diameter of the eye (which does not change during transformation) of the transparent specimen of Figure 14 is slightly longer than the length of the snout; in the just transformed manini the eye diameter is contained about 1.5 times in the length of the snout. The osteological changes which accompany the changes in the proportions of the head were not investigated.

A slight increase in standard length occurs during the metamorphosis to juvenile form. After 5 days in an aquarium, three transforming specimens, 24.1–25.0 mm. in standard length, increased 1.2–1.5 mm. in standard length. Most of the increase is attributable to the prolongation of the snout.

A remarkable lengthening of the digestive tract takes place during transformation (Fig. 3). In a period of 4 to 5 days the total length of the alimentary tract of the manini increases about three-fold. This lengthening occurs at the time of a change in food habits from feeding on zooplankton to feeding on algae (see pp. 222–223).

The teeth of the manini acronurus just before transformation are very different from the simple conical teeth of the postlarval manini (as seen in 6.6 to 7.0 mm. specimens). They are close-set and flattened with denticulations on the edges similar to adult teeth. There are about 14 of these teeth, each with 6 or 7 denticulations, in the upper jaw with a broad gap between teeth at the symphysis of the jaw. There are 14 such teeth in the lower jaw with 5 denticulations each. During transformation 8 large adult-type teeth (with about 12 denticulations), which are preformed within the premaxillary bone above the upper series of larval teeth, grow down over the larval teeth which are shed. The more medial of these large teeth are the largest and the first to emerge. In the lower jaw the same process occurs. Six large adult-type teeth with 7 denticulations grow over the larval teeth. Larval teeth lateral to these large ones may persist beyond the period of transformation.

The sequence of tooth replacement is not without variation from specimen to specimen. At the stage when the scales are just completely formed on the body some specimens have fewer than 8 upper and 6 lower teeth in position. Some specimens taken at night lights in deep water appear to be getting their adult teeth prematurely. One specimen of *Acanthurus triostegus triostegus* obtained at a night-light trap at anchorage at Christmas Island already had 6 large upper and 2 large lower teeth.

GROWTH

No information could be found in the literature on growth of any species of surgeonfish. The closest family, phylogenetically, to the Acanthuridae in which growth data are available for comparative purposes is the Teuthididae (Siganidae of most authors). Like the acanthurids, the teuthidids are herbivorous (Suyehiro, 1942; Al-Hussaini, 1947). Whitehouse (1923: 68–70, 83–85) reported that juveniles of *Teuthis java* grew from a length of 25 mm. in April to 75 mm. in September in Silavatturai Lagoon, Tuticorin, India. Ommanney (1949: 48–49) stated that *Siganus corallinus* (= *Teuthis corallinus*) reached a length of 180–220 mm. after 2 years' growth, and about 280 mm. at the end of the third year, in Mauritius.

Information on growth of the manini was obtained by the rearing of fish in a tank of the Hawaii Marine Laboratory, at Coconut Island, Oahu, analysis of the progression of modes among the juveniles of Figure 6, recovery of young fish marked by fin clipping, and the recovery of tagged adults. The data are discussed separately under these headings below.

The standard-length measurement for all of the work on growth of the manini is the length from the tip of the snout to the middle of the

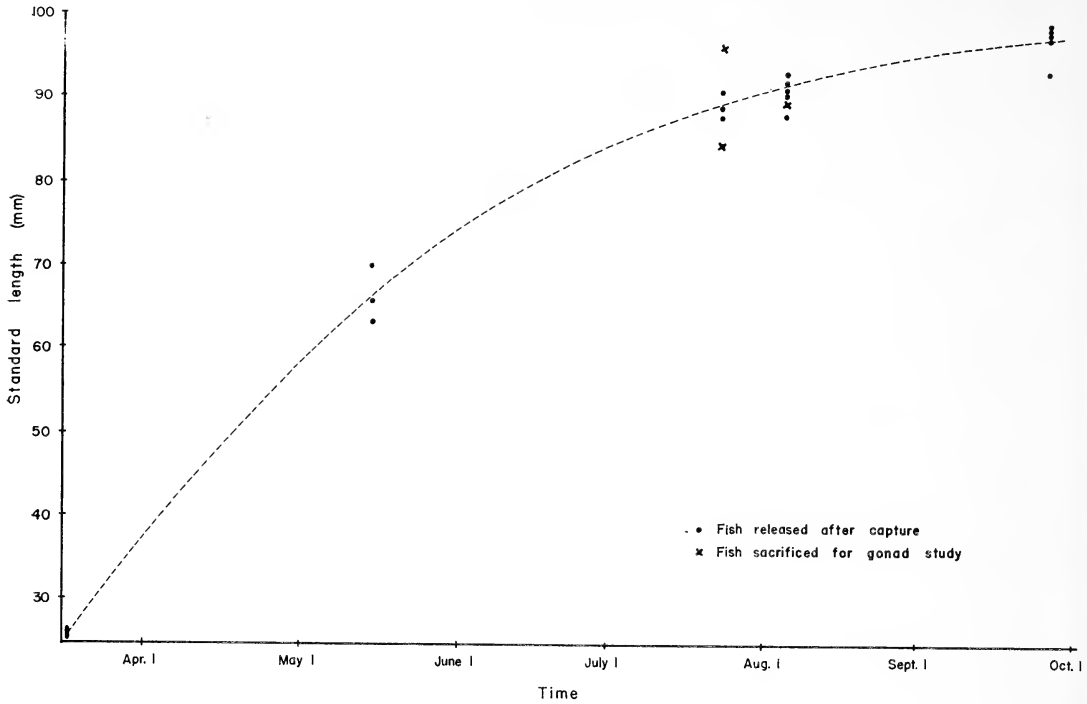

FIG. 18. Growth of *Acanthurus triostegus sandvicensis*. Based on 10 juvenile specimens, 25 to 27 mm. in length, released in a concrete tank at Coconut Island, Oahu, Mar. 17, 1953.

dorsal black bar posteriorly on the caudal peduncle. It was found that this measurement could be made with greater accuracy on living fish than the usual standard length to the base of the caudal fin (i.e., posterior edge of hypural plate). The original measurements are herein retained for all tables, graphs, and discussion (and designated simply "standard length"), rather than converting to true standard length. Should the latter measurement be desired, it may be obtained by increasing the peduncular bar length by 3.5 per cent.

Growth of Captive Fish

Ten manini, 25–27 mm. in standard length (mean length 26.4 mm.), were placed in a concrete tank at Coconut Island on March 17, 1953. The tank measures 34.7 × 10.8 ft. and is an average 3.9 ft. in depth. A constant supply of sea water is pumped into the tank. When the fish were introduced, no other fishes were present and the walls were covered with an exceedingly luxuriant growth of many species of algae. The top of the caudal fin of the 10 juveniles was removed to permanently mark them (see below) as a safeguard against the possible addition of more manini to the tank by other persons.

The growth of these fishes is recorded in Figure 18. The 3 fish captured on May 13 (mean length 66.0 mm.) had grown an average of 20 mm. per month since March 17. On August 6 all of the manini were caught (2 had disappeared and 3 were killed for gonad study). They averaged 90.9 mm. in standard length. By September 27 they had grown to an average standard length of 94.3 mm.; thus the average rate of growth from August 6 to September 27 had diminished to 1.8 mm. per month.

The manini were caught by seining the tank after partially draining it. The efforts to catch them on September 27 failed several times, and much of the algae was detached from the walls of the tank before all of the fish were netted.

Following this the amount of algae on the walls remained slight and apparently insufficient to support the growth of the fish. The 5 remaining manini were measured again on November 19. They were thin, and instead of growing they lost an average of 1.3 mm. in standard length. Manini this size shrink nearly 3 mm. in standard length when preserved in 10 per cent formaldehyde solution.

Growth Measurement from Progression of Modes

The collections of juvenile manini from Kewalo Basin to Makapuu Point, Oahu, plotted in histogram form in Figure 6 permit an estimate of the early growth rate by analysis of the progression in standard length of prominent modal groups from week to week. By this method the growth rate of juvenile manini from about 26 to 45 mm. in length is computed at about 12 mm. per month. Particular reference was made to the mode which first fully appears on the graph on April 17.

Growth of Marked Juveniles

Before undertaking the marking of juvenile manini in the field by fin clipping, experiments were performed in aquaria to test the possibility of fin regeneration. One pelvic fin and the posterior part of the soft portion of the dorsal fin were cut from 3 juvenile manini averaging 27.5 mm. in standard length. Although the fins were severed at the juncture with the body they regenerated rapidly and were nearly completely formed in a month. In a second experiment the top few rays of the caudal fin were cut away as well as the upper corner of the hypural plate to insure the removal of all fin elements. This cutting resulted in the permanent deformation of the caudal fin of the fish.

Ten manini, 28.5 to 30 mm. in standard length (mean 29.25) were caught at the Ala Wai Canal near its entrance to the Ala Wai Yacht Basin on April 24, 1953. The top of the caudal fin of these fish was removed and they were released in the same area. Three of these marked fish were recovered, 1 on May 2 which measured 32.5 mm. in standard length and 2 on May 15 which were 34.8 and 37.0 mm. long (Fig. 19). The average growth rate was 9.6 mm. per month.

Ninety-six juvenile manini, 25–28 mm. in standard length (mean 26.6 mm.), were caught, marked, and released in a Diamond Head tide pool on May 10, 1953. A total of 11 were recovered from this pool on three different dates (Fig. 19). The average growth rate of these fish was 12.9 mm. per month. The 4 manini of this group which were recovered on June 23 ranged from 42.5 mm. to 48 mm. in standard length and averaged 45.1 mm. When first caught with the 92 others on May 10, these fish were a part of the prominent mode which may be seen centered on about 26.5 mm. standard length on the graph for this date in Figure 6. This same mode is still apparent in a sample of 147 fish which were collected at Diamond Head on June 23 in an effort to recover marked fish. At this time the mode is composed of 27 fish, 40 to 49 mm. in standard length with a mean of 43.3. Since the 4 marked manini taken on this date are distributed well within the mode and of larger average size than its mean value, it is concluded that the fin clipping did not retard the growth.

The difference in growth rate between the Diamond Head marked manini and the Ala Wai marked fish may be associated with the difference in algal flora of the two areas. Algal growth in the latter area is sparse; it consists primarily of diatoms. The extraordinary growth rate of the captive manini in the Coconut Island tank is probably also associated with the nature of the algal food supply; the stand of algae was much greater than normally observed in reef or bay areas around Oahu. Invertebrates, including herbivorous types such as echinoids, gastropods, and decapod crustaceans, were present in the tank. It is assumed that the large supply of algae was primarily due to the lack of herbivorous fishes. When introduced to this unusual environment, the 10 juvenile manini were given an unprecedented opportunity for rapid growth.

In view of the more normal environment of the Diamond Head tide-pool region and the similarity in growth rate of marked fish from this region to the rate computed from the progression of modes, 12–13 mm. per month is

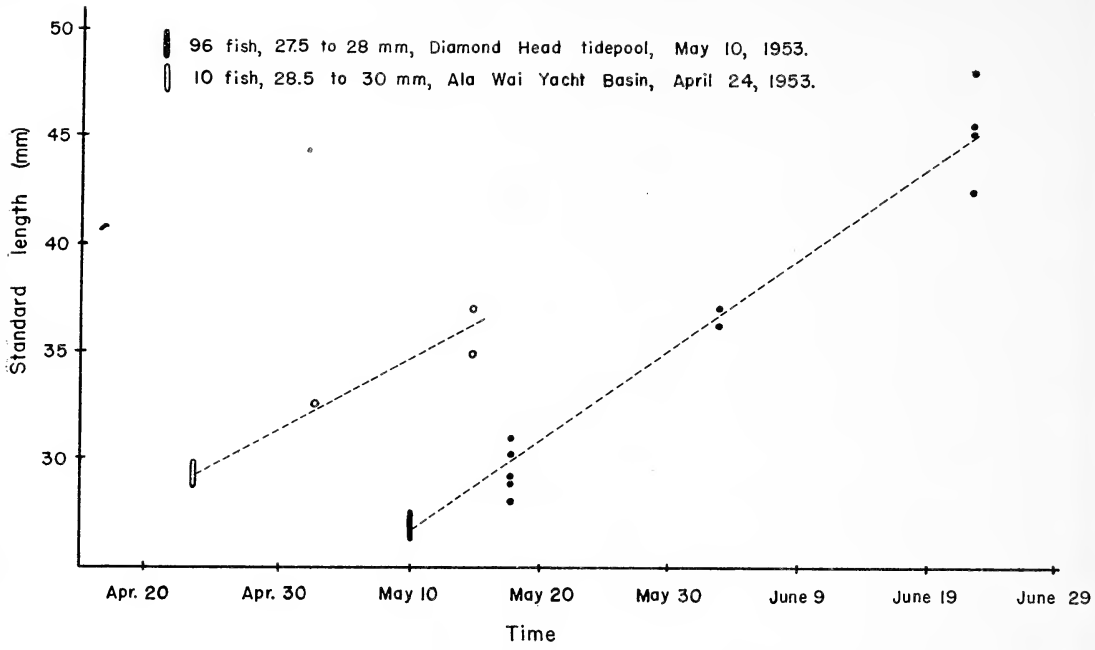

FIG. 19. Growth of juvenile *Acanthurus triostegus sandvicensis* on Oahu. Based on recovery of marked fish.

considered as the probable rate of growth in spring of early juveniles of the bulk of the Oahu manini population.

The growth of juveniles in the winter ceased. This was first noticed from shallow-water collections and observations made during the fall and winter months of 1952–53. Up to November, manini less than 40 mm. could usually be found in the collections or seen in the water. In late November, December, and January no specimens less than 40 mm. were found, but the 40 mm. size persisted. This suggests that the last incoming juveniles of the season, which enter tide pools in early October, grow to a standard length of about 40 mm. by November and then stop growing. During the next two winters the same phenomenon was noted.

In order to demonstrate this cessation of growth and to ascertain the time when growth is resumed, 22 juvenile manini, 40 to 72 mm. long, were caught with a dip net, marked by fin clipping, and released on the nights of January 5 and 6, 1954, at the entrance of the Ala Wai Canal to the Ala Wai Yacht Basin, Oahu. Fish were taken at both the northwest (Waikiki Yacht Club) and southeast shores of the canal entrance. On the two sides of the canal three basic methods of fin clipping were utilized: the top of the caudal fin was removed, the bottom of the fin, and both the top and bottom. Manini of variable size were chosen for each category, and another fin was cut on each specimen. Also any distinctive color marks (usually at the base of the pectoral fin) were noted.

Subsequent efforts to recover the fish were limited by conditions of wind, tide, and turbidity of the water. Although more subject to the effects of turbidity than exposed shores, the Ala Wai area was preferred, for fish are more restricted to the shore area because of the mud bottom away from the bank of the canal. Fish of this size in a region such as Diamond Head move well out on the reef where the broader area, deeper water, and action of surf make them difficult to capture and recapture. Although, as mentioned, some of the larger manini come into tide pools at night, their numbers are not sufficient for such a marking program.

Since fish were measured alive with a light at night, difficulty was experienced in obtaining

precise length determinations. Although the lengths were recorded to 0.5 mm., it should be added that variations as great as 1 mm. from the original measurement were noted in unbiased tests of accuracy.

Eleven of the 22 marked fish were recovered; all from the area of release. Two of these were recaptured a second time. Of the 9 fish taken before February 1, few, if any, showed significant growth (Table 8). The 4 recovered on February 21 and 27 displayed a definite increase in size, indicating a resumption of growth during this month in the area tested and for the year 1954.

One other marked fish caught in February and 2 in early March had regenerated the fin other than the caudal fin which had been cut and could not be distinguished from at least 1 other fish of their respective caudal fin categories.

Although there is some indication of a relationship between increasing water temperature and the onset of growth of these manini, the temperature data are inadequate to establish any definite correlation. Temperatures were taken in the canal at night between 9:30 and 12:00 P.M. about 3 in. beneath the surface (Table 9).

It should be emphazied that the temperature at the mouth of the Ala Wai Canal probably varies much more in a day or from day to day than the sea surface temperature off Oahu (mean water temperatures for Honolulu in 1955 are given in Hydrographic Office, 280, as follows: January 24.0; February 23.6; March 24.1). The Ala Wai area is not large and the water is therefore more subject to change due to variation in insolation and atmospheric temperature than the open sea. Probably more important are the changes produced due to variation in the run off of water from Palolo and Manoa valleys which drains to the canal and to the ever variable tides which affect this estuarine region. In order to provide adequate data for the determination of a correlation, temperatures should have been taken at regular intervals each day and an analysis of growth made in terms of average daily water temperatures.

TABLE 9

TEMPERATURE AT THE MOUTH OF THE ALA WAI CANAL

DATE	TEMP. (° C.)
Jan. 5	22.8
Jan. 20	23.2
Feb. 1	23.1
Feb. 27	25.3
Mar. 2	24.7
Mar. 21	24.9

Growth of Tagged Adults

The first tag used on the manini was the Atkins type (Rounsefell and Kask, 1945: 330, fig. 1). It consisted of a single rectangular piece of white cellulose acetate, 5 × 28 mm. in size, and was attached through the back of the fish beneath the posterior part of the dorsal fin with 4-lb. test monofilament nylon. Two small adult

TABLE 8

RECOVERY SIZE OF JUVENILES OF *Acanthurus triostegus sandvicensis* MARKED ON JANUARY 5–6, 1954

STANDARD LENGTH WHEN MARKED (mm.)	STANDARD LENGTH WHEN RECAPTURED				
	Jan. 20	Jan. 26	Feb. 1	Feb. 21	Feb. 27
40.0	41.0				
46.5	47.0				
49.0					54.5
51.5				57.0	
55.0	55.5			60.0	
55.5	55.0				
56.0		56.5			
64.0			64.0		
66.5		66.0			
70.5	70.5				
72.0	72.0			79.0	

manini were tagged and held in a tank at Coconut Island. Within 3 weeks the tags were no longer present on the fish. They were recovered from the bottom of the tank with the loops of nylon intact, thus indicating that the nylon had pulled through the flesh.

The same type of tag was then threaded through the upper part of the hypural plate of the 2 fish. As they swam, the tag of each oscillated slightly as it was drawn along in a position just above the caudal fin. Three months later both tags were in place, and the method looked auspicious. On March 3, 1953, while operating from the fishing vessel "Friendly Isle" owned by Samuel Kaolulo, 50 adult manini were tagged in this manner. Two fish were recovered 5 days later, both in the vicinity of the point of release. No other recoveries were reported. The two Coconut Island manini lost their tags before 6 months elapsed, and further plans for tagging by this method were abandoned. Disappointing results with Atkins tags have been reported by other authors, such as Fraser (1955).

Petersen disk tags were then tried. Since stainless steel seemed most promising among the metals commonly used to attach these tags (Calhoun, Fry, and Hughes, 1951), this material was chosen for initial trials. Considerable difficulty was experienced, however, in bending the free ends of the wire on a struggling fish, a disadvantage clearly pointed out by Calhoun *et al.* Attention was then shifted to nonmetallic substances, of which nylon seemed the most propitious. It is superior to metal in its pliability, nontoxicity, and in not being subject to electrolytic action or fatigue. In order to keep the disks in place, the ends were melted into knobs with a flame (Fig. 20). The position of the tag on the fish is shown in Figure 21. (For a detailed discussion of this tagging method, see Randall, 1956*a*.)

FIG. 20. Petersen disk tag used in tagging *Acanthurus triostegus sandvicensis* on Oahu. The ends of the monofilament nylon connecting the disks have been melted into knobs with a cigarette lighter. The heating caused a blackening of the one knob which is visible.

On August 6, 1953, 3 captive adult manini were tagged with plastic disks by 60-lb. test monofilament nylon (diameter, 1 mm.) and 1 with stainless steel wire.

Seven weeks after tagging, all 4 fish, along with 6 untagged fish which were measured at the time the 4 fish were tagged, were caught and remeasured. The 6 untagged fish, which had a mean standard length of 86.3 mm., had grown an average of 6.6 mm. The 3 tagged with nylon (mean standard length, 84.4 mm.) grew an average of 7.7 mm. The 93 mm. fish whose disks were attached with stainless steel wire added the smallest increment of growth, 2.5 mm. Although there are insufficient data for definite conclusions, it seems apparent that manini tagged with Petersen disk tags fastened with monofilament nylon are capable of normal growth.

One of the fish which survived 11 months until July when the tank was needed for other purposes still retained its disks fastened with nylon. It was noted that the tagging wound was small, and there was no evidence of deterioration of the nylon.

Since the experimental tagging demonstrated no obvious fault in this method, field tagging was begun. Forty-five manini were tagged with hand-made tags. This proved to be most time consuming, and assistance was requested of and granted by the Hawaii Division of Fish and Game. Manufactured tags of laminated cellulose acetate (Fig. 20) were purchased. In order to publicize the tagging, posters (Fig. 21) were

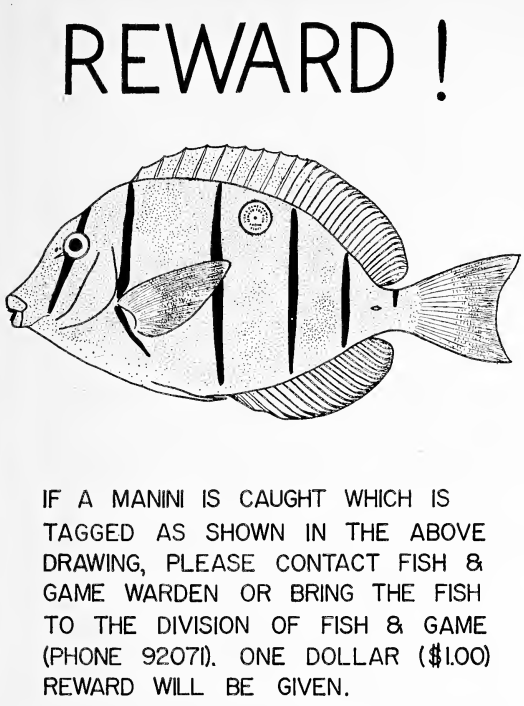

FIG. 21. Poster used to publicize tagging of *Acanthurus triostegus sandvicensis* on Oahu.

distributed by game wardens. Carl M. Nemoto, then working for the Division of Fish and Game, tagged a total of 1,157 manini, 70 to 152 mm. in standard length, from July 6 to November 23, 1954. Forty-five additional fish were tagged on May 4 and June 6, 1955. The tagging was carried out from Kaolulo's vessel between Kewalo Basin and Koko Head, Oahu. The manini were caught in traps, tagged, measured, and released at the place of capture, which was recorded.

Due to the difficulty of using a flame when tagging from a vessel exposed to the strong winds of the Kaiwi Channel (Molokai Channel), Nemoto decided to tag most of the fish by crimping brass leader sleeve on one end of the nylon (the other end was melted into a knob prior to the departure of the vessel). This method was devised by Kenji Ego of the Division of Fish and Game.

Of the total of 1,247 manini tagged with disk tags, there have been 281 recoveries. Of the recovered fish, 173 have been returned alive, providing the opportunity for re-release. Twenty-four of these have been caught again, and 3 have been taken a third time (these recoveries are included in the 281 mentioned above).

The following table shows the lapse of time by 2-week periods between the release and recovery of tagged manini.

The fish with the longest recovery time was tagged on September 21, 1954, and recovered on July 29, 1955.

The explanation of the large number of manini recovered in the first few weeks following release and the sharp drop in returns thereafter probably involves a number of factors, such as mortality, loss of tags, and movement from the immediate area of release.

It is known that at least some loss of tags has occurred, for manini with the tagging wound but without tags have been noticed by fishermen. Since no fish have been seen with a tag in the process of moving up through the back and dorsal fin, it is assumed that most of the early losses, at least, occurred from a dropping off of a disk because of the knob being too small or the brass inadequately crimped. Analysis of the returned tags indicated that the knobs were too small in many cases. When the diameter of the hole in the disk is 1 mm., the knob should measure at least 2 mm.

TABLE 10

RECOVERY TIME OF TAGGED ADULTS OF *Acanthurus triostegus sandvicensis*

WEEKS FOLLOWING RELEASE OF FISH	NO. OF FISH RECOVERED
2	96
4	57
6	42
8	25
10	17
12	9
14	6
16	5
18	4
20	4
22	3
24	5
26	2
28	2
30	2
34	1
40	1

Movement from the trap area could account for a diminution in recoveries of tagged fish; however, evidence is strong against at least extensive migration by this species (see section on migration).

The marked drop in number of recoveries still seems too high to be accounted by any or all of the above reasons. One other possibility exists which is supported by the extraordinary high percentage of early returns. A tagged manini may show a greater predilection to re-enter a trap than untagged manini to enter a first time. This phenomenon has been conclusively demonstrated by Lawrence (1952) for bluegill sunfish in Iowa farm ponds. If such a tendency exists, it might be expected to be greatest in the fish soon after release and gradually abate with time. One manini was caught, tagged, released near the next trap, and caught again in this trap a few minutes later.

The 173 tagged fish which were returned alive were measured alive a second time by Nemoto and released. The remaining tagged manini were measured after they had died, and usually not when fresh but following partial drying and/or freezing. Seventeen of the latter group were recovered within the first 2 weeks following tagging. These fish were all from 1 to 7 mm. shorter than when first measured. The average shrinkage was 3.53 mm. The average standard length of these specimens measured to the peduncular mark is 109.8 mm. The average shrinkage per millimeter of length is therefore 0.032 mm. A correction was made for each fish which was measured dead (unless freshly dead) by multiplying its recovery length by this factor and adding the product to the length.

A total of 70 tagged manini were measured alive a second time following recovery within 2 weeks of tagging. Surprisingly, 46 of these were from 1 to 5 mm. shorter than when first measured; 10 were the same size; 14 were from 1 to 3 mm. larger. The average "growth" was —1.06 mm. A t test applied to these data to ascertain the probability of obtaining such a distribution from a population in which no actual change in length occurred resulted in a t value of 5.1. With 69 degrees of freedom this gives a probability of less than 0.001 of getting a higher t value; thus the null hypothesis of no significant difference is rejected. Since the same person measured the fish both times, the reason for the significantly shorter length is not apt to be any bias in measurement. The shorter length is probably due to shrinkage from starvation in the traps. Manini which are caught in traps may have been held in the traps for a week or more. Although both measurements are made on fish caught in traps, the effects of confinement would be expected to be greater on fish spending another period in traps within 2 weeks of their first.

In order to test the hypothesis that actual shrinkage occurs during starvation, 17 trap-caught adult manini (none showed evidence of long sojourn in traps), 112 to 131 mm. in standard length, were tagged, measured, placed in two large aquaria, and allowed to starve. Eleven days later the 5 fish which survived were remeasured. A definite shrinkage of from 1 to 5 mm. (mean 3.4 mm.) had taken place. The measurements were made by Nemoto.

The large amount of variation (—5 to +3 mm.) in the series of differences between the measurements made on the 70 fish when tagged and recovered within 2 weeks was unexpected. When it is realized that five different sources contribute to this variability, it is more comprehensible. There is the possible error in the first measurement of a living fish. The second measurement of this same fish constitutes an independent source of error. The shrinkage due to starvation is a third. Some manini which are caught have not been in a trap more than a few hours and will not have shortened at all; others held prisoner for a week or more may have shrunk several millimeters. Some manini initially caught after a very short stay in a trap, tagged with a minimum of injury, and recovered a full 2 weeks later after another brief period in a trap might have grown about a millimeter; thus growth itself probably forms a fourth source. An important fifth source of error in the measurement of the dead tagged fish is the variation in shrinkage after death. All of this variability has necessitated a statistical approach to the analysis of the data, and for this purpose the large number of recoveries has been most welcome.

Only those manini recovered after spending

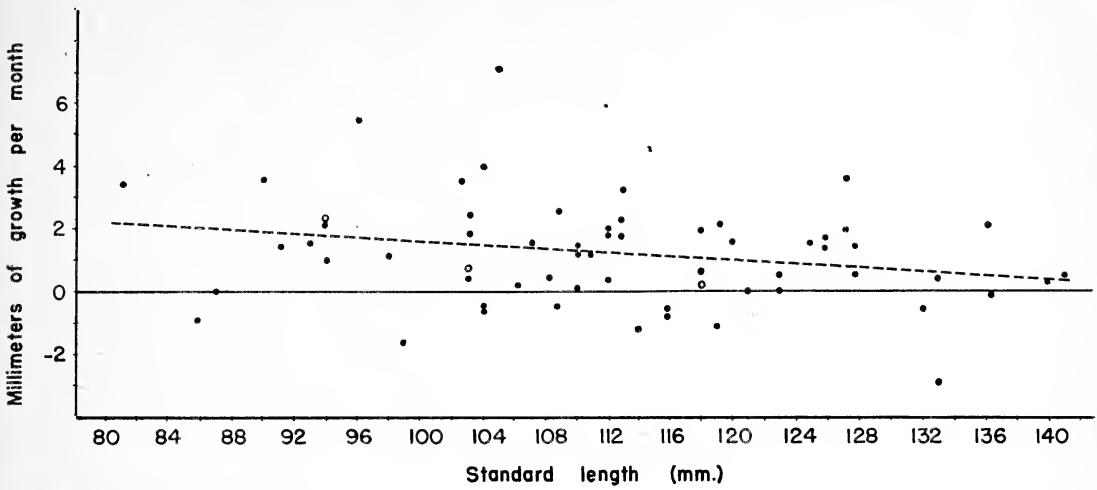

FIG. 22. Growth of *Acanthurus triostegus sandvicensis* on Oahu during the period Jul. 6 to Nov. 19, 1954. The points represent growth increment of tagged fish recovered after at least 1 month in the water. Circles indicate the superposition of one point on another. The dotted line is the regression of growth on standard length.

a month or more in the water following being tagged were utilized for growth study. In Figure 22 the data from 68 such fish, tagged between July 6, 1954, and September 28, 1954, are plotted. The dotted line represents the regression of millimeters of growth per month on standard length. The regression coefficient "b" (slope of the regression line) is —0.0292. The *t* value testing whether this regression differs significantly from zero is 2.085. With 66 degrees of freedom, the probability of getting a larger value of *t* is 0.04; thus the null hypothesis of no significant regression is rejected.

The comparison of the regression line with the upper part of the growth curve of Figure 18 is favorable. The average growth rate of the captive fish from August 6 to September 27 was given as 1.8 mm. per month. The average rate for this size range (90.0 to 94.3 mm.) from the regression line is 1.74 mm. per month.

In order to further confirm the finding of cessation of growth in winter, 155 manini were tagged on November 19 and November 23, 1954, by Nemoto. Twenty-five of these fish were recovered from December 23, 1954, to February 18, 1955 (see Fig. 23). Their average rate of growth is —0.112 mm. It therefore seems likely that no growth occurred during this period.

Tagged manini, recovered after a month or more in the sea, which were at liberty during winter and either fall or spring months have not yet been considered. Data from these fish are presented in Table 11.

If it is assumed that these 22 fish did not grow during any part or all of the 3-month period beginning November 19, and the growth rate of each is computed only from remaining months, an average growth rate of 1.8 mm. per month is obtained. This compares favorably with the rate of growth as indicated in Figure 22 (the average standard length in Table 11 is 110.6 mm.).

AGE

In view of the lack of winter growth of the manini it was hoped that annuli might be detected on the scales; however, none could be seen. Even the circuli of the tiny scales of this species are not very distinct. Cross-sections of vertebrae and otoliths were also examined, but with negative results. It was necessary to grind otoliths to about 1 mm. thickness and view them with subdued light under a compound microscope before any concentric rings could be seen. These were numerous and variable, and none were more sharply defined or grouped closer together than others.

TABLE 11

GROWTH OF *Acanthurus triostegus sandvicensis* RECOVERED AFTER 1 MONTH OR MORE FOLLOWING TAGGING

(Period of tag retention includes both winter and fall or spring months, 1954–55)

DATE RELEASED	DATE OF RECOVERY	STANDARD LENGTH	MEASURED DEAD	GROWTH (mm.)
Jul. 6	Dec. 14	105	×	3.4
23	Mar. 25	110		3.5
30	Dec. 23	115.5		5.5
Aug. 10	Feb. 6	113	×	7.8
10	Feb. 22	110		3.0
13	Jan. 28	98	×	3.1
27	May 17	97		8.0
Sep. 3	Feb. 6	101	×	7.2
3	Mar. 25	102		3.0
21	Jan. 24	98.5		4.0
21	Feb. 18	123	×	7.0
21	Feb. 21	105	×	7.4
21	Jul. 29	101		4.0
28	Dec. 23	121	×	1.8
28	Jan. 21	114		2.0
28	Mar. 25	122	×	1.8
28	Apr. 23	124		1.0
Nov. 19	Mar. 1	105	×	3.8
19	Apr. 5	152		1.5
23	Mar. 19	119		0.5
23	Apr. 27	105		3.0
23	Jul. 6	106.5		7.5

The next approach to obtaining the age of manini was the preparation of the length frequency curve of Figure 24. As the recruitment of the manini is seasonal, it seemed possible that year classes might stand out as modes on such a graph. At least for this curve, however, no definite modes are apparent. Probably the long period of recruitment (February to October), coupled with individual variation in growth, precludes the formation of distinct modal groups in standard length.

Age determinations of the manini would therefore seem possible only by rearing of fish, recovery of tagged fish (tagged at a size small enough to predict the age from growth rate with reasonable accuracy), or gross estimates from growth rate and knowledge of the maximum size.

Although the age attained by the manini is unknown, the following information on the age of two surgeonfishes supplied by Spencer Tinker, director of the Waikiki Aquarium, indicates that at least some acanthurids are long-lived. Two unicorn fish (*Naso unicornis*) which were present in the aquarium when an employee arrived in 1935, lived until they succumbed as the result of an accident in 1955. In 1940 several specimens of *Acanthurus xanthopterus* approximately 5–6 in. in length were placed in the aquarium. Two of these survived until 1951 in a small tank together; they had reached a size of about 20 in. At this time one slashed the

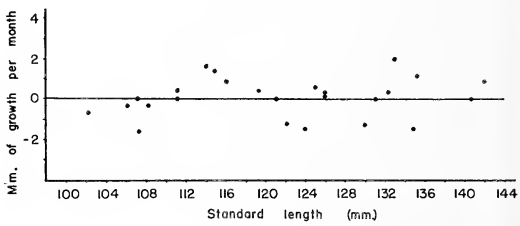

FIG. 23. Growth of *Acanthurus triostegus sandvicensis* on Oahu during the period Nov. 19, 1954, to Feb. 18, 1955, as based on the recovery of tagged fish which were in the water 1 month or more. The horizontal line was added at the zero point to facilitate comparison of the distribution of points with Figure 22.

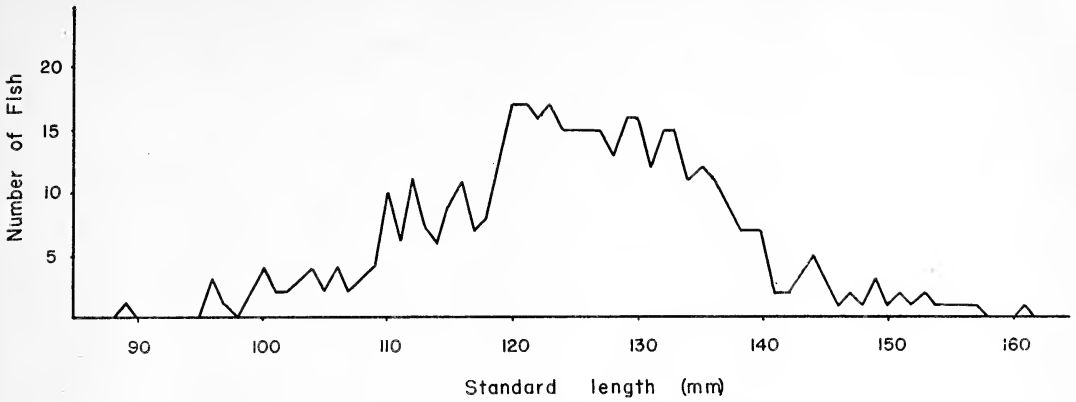

FIG. 24. Length frequency distribution of *Acanthurus triostegus sandvicensis*. Based on 426 specimens caught in traps from Kewalo Basin to Koko Head, Oahu, from Apr. 2 to 9, 1954.

other with its caudal spine and the latter ultimately died. The remaining fish died in 1955 because of an accident.

BEHAVIOR

Migration

Small juvenile manini tend to remain in the tide pool or shallow water area to which they first come from the pelagic state. Some evidence for this has already been presented. Of 176 juveniles taken in the weekly collections during a season from the tide pool of Figure 4, only 19 were 30 mm. or more in standard length and hence definite migrants to the pool from other areas. Since all of the fish in this pool were killed with rotenone each week, a much greater movement to such a large unoccupied area would be expected from the smaller adjacent pools if the species did not exhibit a tendency to remain in one location. When the adjacent pools were sampled for manini, they invariably contained many more specimens 30 mm. or larger, than less than 30 mm. It should be emphasized that these pools are isolated from one another for only about an hour or less during the infrequent low tides less than 0.0 ft. Even in areas like the shore of the Ala Wai Canal and the Ala Wai Yacht Basin where adjacent areas are freely available at all times and essentially identical in cover and food supply, appreciable movement does not take place. This is attested by the success in recovery of marked fish at the mouth of the Ala Wai Canal (Fig. 19, Table 8). Failure to take more of these fish was not due to their movement out of the area but to the difficulty in catching them. Less than one-fourth of the manini sighted were caught, and probably many others were hidden from view under large rocks, etc. None of the fish were taken farther than 20 ft. from the point of release, although the shore was searched as much as 100 ft. away.

On March 7, 1953, a juvenile manini, estimated 36 mm. in standard length, was seen next to the sea wall of the Ala Wai Yacht Basin beside a pier. It was probably among the first manini of the season to come into the area, and was the only individual this size visible for over 100 ft. of sea wall on either side of the pier. On the 9 different days up to March 28 when attempts were made to find this fish, it was seen. Its greatest movement from the place where first observed was only 12 ft. On March 28 it was caught (measured as 41 mm.), and the posterior part of the soft portion of the dorsal fin removed in order to identify it with greater certainty in further observations. It was found on 10 different days up to May 2, but never more than 12 ft. to either side of the pier. On April 24 the dorsal fin had almost completely regenerated and by May 2 the fin appeared normal.

As juvenile manini grow, they migrate seaward from the tide-pool zone (in the harbor area, as mentioned, the larger fish remain in shallow water because of the lack of cover and

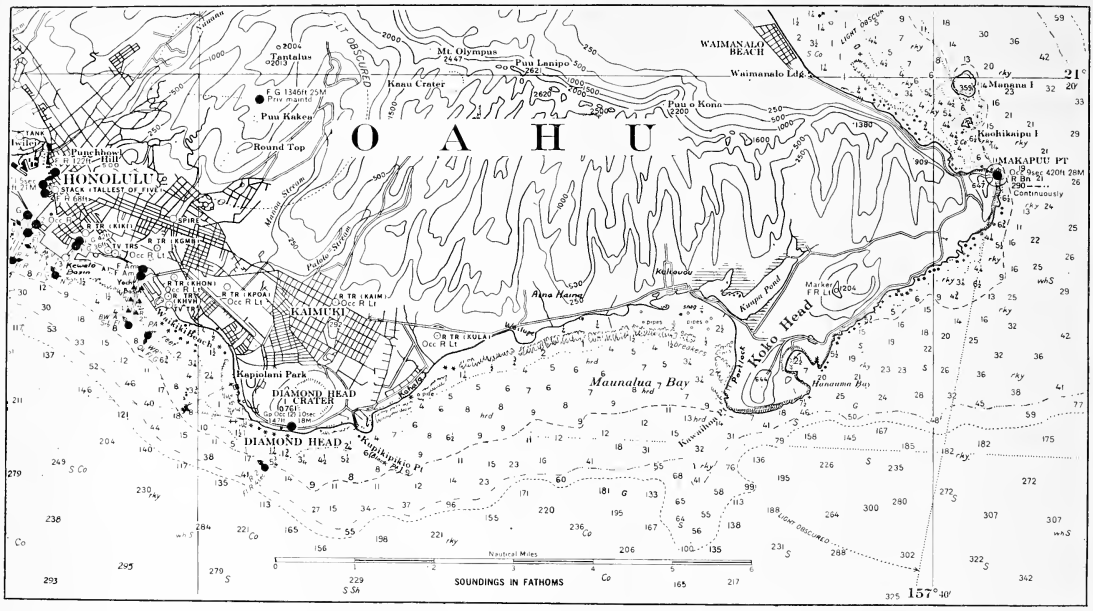

FIG. 25. Southeastern coast of Oahu, Hawaiian Islands (after U. S. Coast and Geodetic Survey Chart No. 4110).

the lack of algae on the mud bottom away from shore). This movement is demonstrated in the graphs of Figure 6. The relative size of any one modal group is progressively smaller in subsequent collections (predation would have to be extremely heavy to achieve the same diminution). The one seeming exception is the large collection of May 29. This, however, was made from a very large pool at Diamond Head which averages about 4 ft. in depth. A higher percentage of larger manini were expected from this collection than previous collections which were all made in pools less than 2 ft. deep.

Information on movements of adult manini was obtained from the recovery of tagged fish. Unfortunately, exact locality data for the areas of release and recovery were usually not available. Since Nemoto was operating from a commercial vessel solely by virtue of the kindness of Kaolulo, he could not delay the fishing to take bearings or soundings. Most locality data from fishermen who recovered tagged manini were also very nonspecific. As a result, little is known of local movements of adults, and only migrations from one major area to the next or the lack of such migrations could be ascertained.

Kaolulo's traps are arranged in groups, most of which are well separated. Nemoto designated these areas as offshore from the following: Yacht Basin, Royal Hawaiian Hotel (Waikiki), Natatorium (near Kapiolani Park), Diamond Head, Black Point, Kahala, KULA antenna, Wailupe, Aina Haina, Kuliouou, Niu Peninsula, Portlock, and Koko Head (Fig. 25).

Of the 281 recoveries of tagged manini 237 were made by Kaolulo; 126 tagged fish, most of which were early recoveries by Kaolulo, were returned to the Division of Fish and Game with no record of where they were caught. This difficulty arose because of his resorting to memory alone to recall the area where tagged fish were taken. When he caught several fish he usually admitted that he could not be sure where any of them were caught. He was finally persuaded to keep record of locality by tag number.

One hundred and thirty-two tagged manini were recovered which exhibited no definite migration. Ignoring fish released in Kewalo Basin for the moment, this leaves only 11 records which indicate that some migration might have occurred. Five of these were fish which were displaced from their home area by movement of

the vessel to the next area and which apparently returned to the home area. One was caught at Wailupe, released at Black Point, and caught again at Wailupe. The same fish was not released the second time until the Kuliouou area was entered. It was caught a third time back at Wailupe. Another Wailupe manini was released opposite the KULA antenna and was recovered at Wailupe. Two fish were caught at Black Point, released farther offshore at Kahala, and caught again at Black Point. The remaining 6 records are as follows: 1 fish supposedly migrated from Kuliouou to Wailupe; another went from the KULA antenna to Niu Valley; 2 apparently went from Kuliouou to Wailupe; the last 2 swam from Black Point to Kuliouou. The possibility of error must be kept foremost in mind for all of these apparent migrations. The 2 manini which moved from Black Point to Kuliouou were both caught by Kaolulo on the same day, which seems unusual.

In view of the manner in which the locality data have been reported, it is surprising that more alleged migrations have not taken place. It is therefore concluded that extensive migrations of this surgeonfish probably do not normally occur.

Of the 172 tagged manini which were released a second time 125 were set free on Kewalo Basin. Twelve of these have been recovered. One was taken between piers 7 and 8 in Honolulu Harbor. The rest were all captured either at Kewalo or in the Diamond Head direction. One was taken from a tuna boat in the basin, and 2 off the Kewalo breakwater. One locality reads Ala Moana and another Ala Wai. One manini was caught by Kaolulo with no record of locality. Since his nearest trap is off the Yacht Basin, this fish must have migrated at least this far. One manini released at Kewalo was caught at a depth of 30 ft. directly off the Royal Hawaiian Hotel. A fish from Black Point was caught 6 months later at wading depth off Diamond Head not far from Black Point. The most interesting recoveries of Kewalo-released fish are 2 from Kuliouou which were originally captured at Kuliouou and 1 at Wailupe which was first caught off Wailupe. Although, again, the possibility of error must be kept in mind, it seems unlikely that the only 3 examples of extensive migration (about 8 mi.), all of which occurred among the 12 fish recovered following release at Kewalo Basin, could be mistakes. One of the Kuliouou manini was recorded from this area by tag number by Kaolulo. When questioned of any chance of error, he insisted there could be no mistake. An interval of 3½ months elapsed between its release in Kewalo and its final capture. The other Kuliouou fish was obtained from the Young Market in Honolulu. The interval between the release and capture of this fish was 16 days. The Wailupe fish was recovered by Kaolulo 1 month after release in Kewalo Basin. The locality was reported verbally. The intriguing interpretation of these 3 records of long migration is that at least some manini removed from their home area will continue to wander on the reef until they return. Three records are too few on which to base such a conclusion; therefore more data should be obtained by purposely displacing tagged manini considerable distances from the original area of capture.

Aggregations

Adult manini are often observed in large feeding aggregations which slowly move over the bottom. These groups of fish may be dense and cover areas more than 50 ft. in diameter. What appears to be the same school was repeatedly seen in the same general location at the northwestern end of Manana Island. This group of fish was observed in the area in fall as well as during the breeding season. The behavior of individual manini of the school did not seem to differ from that of solitary adults.

One school of about 300 adult *Acanthurus triostegus triostegus* was observed in the northeast side of the pass at Takaroa, Tuamotu Archipelago, over a period of a week. The school moved as a close-knit mass several feet off the bottom, stopping frequently for periods of several minutes to graze algae. One or two *Aulostomus chinensis* were observed to accompany the school, and the manini were almost constantly harassed by *Acanthurus glaucopareius* which chased individual fish. The school moved as much as 300 yd. in several hours.

Juvenile manini are gregarious and are often seen swimming in groups. One group of 11 individuals, all less than about 36 mm. in standard

length, was observed for a period of half an hour at the shore of the Ala Wai Yacht Basin. No fish became separated by more than 12 in. from the rest of the group.

The schooling of *A. triostegus triostegus* during spawning has been discussed previously.

Reaction to Danger

Juvenile manini along the shore of a part of the Ala Wai Canal infrequently visited by man perceive the approach of a person walking along the bank from an average distance of about 20 ft. This distance is contingent on the position of the sun and the depth and turbidity of the water. The usual reaction is a swift darting to some immediate hiding place. If an observer remains immobile, the fish come out of hiding in from about 15 to 25 sec. and resume feeding shortly thereafter. Manini of the same size next to the sea wall of the Ala Wai Yacht Basin, where people pass almost continuously, do not interrupt their feeding at the approach of a person unless some unusual sharp movement is made, at which time they may hide.

The manini in a large tide pool at Diamond Head were observed to have two hiding places, each beneath ledges at the side of the pool. One of these was preferred, and most of the fish swam to it when the pool was approached. When rotenone was spread in the region of this retreat, all of the fish swam rapidly in a direct line to the second ledge, in spite of the turbidity of the water (from the rotenone), even though they had to move in the direction of the observer and pass over a very shallow part of the pool. The part of the pool away from the observer was broader, deeper, free of rotenone at the time, but without good cover. It was evident that the fish were well aware of the location of the best places to seek refuge.

An experiment was designed to determine the time required by juvenile manini to recognize and accept a new site of cover. A small opaque plastic bowl was inverted and placed with one edge elevated from the bottom of a 23 gal. aquarium in which 12 manini, 26 to 39 mm. in standard length, had been kept without a place of shelter for 3 days. Initially this bowl was avoided by all the fish. Fifteen min. elapsed before any fish swam near it. One hr. after the bowl had been added to the tank, the manini were frightened by rapid arm movements all around the aquarium; however none sought refuge in the new shelter. Upon being similarly frightened 3 hr. later, 2 of the smallest fish went into the bowl. Three hr. after this, all of the manini swam to the bowl for cover.

Adult manini are less inclined to seek shelter. Their reaction to an approaching swimmer usually takes the form of retreat. When cover is sought, the hole into which the fish swim usually has two or more entrances. As has been pointed out by Breder (1949*b*: 97) a reaction to attack which alternates between flight and hiding is common among fishes.

Fighting

Juvenile manini may often be seen fighting among themselves in the natural environment. Also, several days after being placed in an aquarium, this behavior becomes noticeable. It increases with time to the extent that it interferes with feeding. After 2 weeks in an aquarium, fully half the diurnal time of 12 juveniles was spent at this activity. The fighting was not associated with territoriality, but took place among all the fish and in all parts of the tank. Three of the larger fish were consistently the aggressors, and the smaller fish usually bore the brunt of their attack, but no definite peck order was established. When only 2 fish were present, however, the larger invariably dominated the smaller and forced it to remain in a corner of the aquarium for much of the day.

A distinct color change, which results in an almost complete reversal of the usual color pattern, accompanies the fighting. The broad pale interspaces between the vertical black bars become very dark, and the upper seven-eighths of the bars change to yellowish white except for a fine dark line in the center of each. On the lower eighth of the body the black bars are faintly visible in their normal width. The more aggressive fish are darker than the less aggressive ones.

The fighting usually involves little actual contact between fish. Most of the time a fish under

attack hastily withdraws, a response which generally satisfies the attacker for the moment. When there is no immediate retreat the two fish circle at close quarters and make pugnacious movements, mostly with the posterior part of the body. When a new manini was placed in the tank, it was attacked with ferocity by all of the other manini, but rarely more than one at a time. The hapless fish was pecked over the head and body, strongly bumped, and lashed at with the caudal spines of the others as it scurried from one part of the tank to the next. A manini twice the size of any in the tank was given the same treatment. After about half hour of incessant attack, this oppressed fish was observed to lie on its side on the bottom and submit completely to the relentless abuse. It was caught and examined shortly thereafter. Only a few small scratches on the fins and two small cuts on the body could be seen. The manini has a much smaller caudal spine than other species of *Acanthurus* and is not capable of inflicting much damage with it. Also the jaws do not seem strong enough to injure other fishes of equal size.

Manini were never observed to fight with other species of fishes. They appear to display a dominant behavior pattern to at least some, however. Six small pomacentrids (*Abudefduf abdominalis*) ranging from an estimated 18 to 38 mm. in standard length were observed to intermingle with 4 juvenile manini about 28 to 36 mm. in standard length at the shore of the Ala Wai Yacht Basin. Although the pomacentrids swam close to one another, they usually avoided coming within a body length of any manini. When one did and this was observed by a manini, the latter responded by a slow sideward movement of the body toward the intruding fish. The posterior half of the manini's body was curved toward the pomacentrid and vibrated slightly. The pomacentrid invariably retreated a short distance.

Breder (1948: 293) observed similar behavior in an aquarium with *A. chirurgus*. He noted that a peck order was established among certain fishes in an aquarium. This involved 4 pomacentrids and 1 gerrid. A small specimen of *A. chirurgus* was added which was about equal in size to the largest pomacentrid. Although the surgeonfish was not bothered much by the other fish at first, it seemed to be low or lowest on the peck order. It was never noted to pursue the others, but was occasionally pecked at by the others. Fourteen days later the peck order was modified and the acanthurid was definitely number one. There was little fighting but all kept clear of the surgeonfish which "showed" its peduncular spine to the more timorous.

I have never observed fighting among adult manini. Larger individuals may display dominance over smaller ones, however.

Behavior at Night

At night, both in the natural habitat and in the aquarium, manini rest on the bottom, usually with the pelvic fins and anal fin touching the substratum, in what appears to be a state of torpor or sleep. In general the body color is darker than during the day. Large dark blotches which may be seen faintly during the day between the vertical dark bars are more conspicuous at night. This resting phase is not without movement, for the pectoral fins are almost in constant slow motion and there are vertical undulations of the median fins. When a light was flashed on a darkened aquarium at night, short movements over the bottom were occasionally found to be in progress. These were directed backward more often than forward.

Usually the manini in an aquarium or a tide pool at night are well dispersed. In the normal environment most of the fish choose a sheltered although not a confining location. Many, however, may be seen in very exposed locations. Breder (1948: 294) observed that *A. chirurgus* rested on the bottom of an aquarium at night in the proximity of some shells, but in no case did it enter or hide in the shells.

If light is turned on a sleeping manini at night, and no sharp movements are made, the fish can be lightly touched or even picked up without its making any effort to escape. If a sharp movement is made in the water of the aquarium, or if the fish is roughly handled, it will dart away for a considerable distance over the bottom. This behavior was put to good use for the collection of this species alive. Using a head lamp at night to locate a sleeping fish, a dip net was cautiously placed in front of the

quarry. A long stick was used to prod the posterior end of the fish which often responded by swimming into the net.

The following observations on sleep were made on 10 juveniles, 27 to 40 mm. in standard length, which had been maintained in an aquarium for 12 days.

With the onset of darkness the fish settled to the bottom of the tank, although they continued to move about, and occasionally these movements would take them above the bottom. After total darkness ensued, 25 min. were required before they entered the state of suspended animation completely. This state was ascertained by lightly stroking the fish with a glass rod. When they ceased to flee from such contact, it was assumed that they were asleep. Since the period of attaining sleep was prolonged by the interruptions, a series of observations on successive nights was necessary to determine the normal period.

The stimulus to sleep was shown to be the onset of darkness and not merely the passage of a definite number of hours of diurnal existence, for the manini remained active for many hours when a light was kept burning above the tank after darkness set in. In one experiment the fish were kept awake for a period of 24 hr. They remained active during the time; however they ceased to feed toward the end of this period and displayed "restless" swimming.

When the fish were kept in total darkness for 24 hr., they remained relatively quiet on the bottom during the entire period. At the end of this period, however, it was noticed that they perceived the immersion of a hand into the tank regardless of how slowly it was inserted.

After 3 hr. of uninterrupted sleep, beginning with onset of darkness, lights were turned on to see how long the state of torpor would persist. In 13 to 14 min. the first 3 fish awakened and began to swim around the aquarium. These were the largest of the 10 manini. The remaining fish awakened according to size; the 2 smallest required 25 and 28 min., respectively. All of the fish displayed very restless swimming, moving constantly back and forth in the aquarium. When the lights were turned off, they required 39 min. to re-enter the state of torpor. No distinction could be detected in the time needed for the different-size fish to go back to sleep.

SUMMARY

1. In the Hawaiian Islands the common surgeonfish, *Acanthurus triostegus sandvicensis* (known in Polynesia as the manini), is found in many different habitats, although never far from coral or rock for shelter and algae for food. The young are abundant in tide pools.

Manini are not numerous in regions of heavy coral cover, although certain other surgeonfishes are surprisingly common there.

2. The eggs and larvae of the manini are pelagic. Eleven acanthurid larvae, 4.2 to 8.7 mm. in length, were taken in eight plankton tows 10–140 mi. from the nearest Hawaiian island. All were from the upper 50 m., although more tows were made in from 100 to 300 m. A higher percentage of acanthurid postlarvae have been found in surface-caught yellowfin tuna than those taken with long line at depths of about 30 to 160 m. Acanthurid larvae are more commonly found in the stomachs of tuna caught inshore than offshore.

3. The limits of temperature tolerated for 1 hr. by manini (both young and adults) appear to be about 12° and 37° C. Chlorinity tolerance for 24 hr. approximates 1.4 ‰ to 37 ‰. The most extreme readings of temperature found on Oahu in waters inhabited by manini were 16.2° and 35.1° C. and of chlorinity, 2.65 ‰ and 21.3 ‰.

4. Apart from the postlarval acanthurids found in tunas nothing is known of predation on the pelagic stages of the manini. In Hawaii, juvenile manini probably constitute prey to carangid, muraenid, synodid, scorpaenid, sphyraenid, cirrhitid, holocentrid, and antennariid fishes, and possibly certain large crabs. In view of the paucity of large piscivorous fishes in Hawaiian waters adult manini are probably relatively free of predation (man excluded).

5. The manini was found to be parasitized by one species of hydroid, four trematodes, four nematodes, two leeches, and six copepods.

6. Difficulty was experienced at one time maintaining manini in aquaria. They died in

about 48 hr., displaying large sores, eroded fins, and excessive mucus on the body. The dominant bacterium was a short, gram-negative rod.

7. The stomachs of 3 postlarval manini 6.7 to 7 mm. in length were examined for food. Two were empty, and 1 contained two appendicularians and a larval polychaete. Of 57 manini in the acronurus (late postlarval) stage taken by night light offshore, 45 were empty, and the rest contained only occasional fish scales or crustacean fragments lodged in intestinal folds, thus suggesting that the acronuri do not feed at night. The guts of 4 unidentified acronuri taken from a skipjack stomach caught during the day were filled with zooplankton.

8. During the first day of transformation from the acronurus to the juvenile state, most manini do not feed at all. Feeding on algae becomes progressively heavier as transformation continues.

Juvenile and adult manini feed almost entirely on relatively fine filamentous algae of numerous species. Little inorganic sediment was seen in the gut contents. When 28 different kinds of algae plus diatoms were offered to manini in feeding experiments, a red alga (*Polysiphonia* sp.) and a green (*Enteromorpha* sp.) were preferred. All of the blue-greens, the red *Asparagopsis*, and one species of the brown alga *Ectocarpus* were not ingested (although these may be found in stomach contents, mixed with other algae).

9. Juvenile manini were maintained in aquaria on algae alone. Fish 26 to 31 mm. in standard length grew at the rate of about 6 mm. per month (temperature 23.0° to 23.8° C.) when fed either *Polysiphonia* sp. or *Enteromorpha* sp.

10. Manini feed almost constantly during the day, and a large volume of algae is passed through the gut. Four juveniles weighing a total of 8.3 grams consumed 10.8 grams of *Enteromorpha* in 1 day and 8.8 the next. Two adults weighing 83.2 and 94.5 grams ate a total of 27.4 grams of *Enteromorpha* in 1 day. The adult fish did not feed as frequently in aquaria as in the natural environment. The larger fish dominated the smaller one and consumed the major part of the algae.

11. Manini showed no response to extracts of algae, and the visual sense alone is needed to locate algal food. The olfactory sense appears to function in feeding only to avoid unsavory material. Chemoreceptor organs in the mouth and possibly tactile organs as well seem to be associated with the acceptance of algae and the rejection of material not utilized as food.

12. The morphology of the digestive system is briefly discussed. The alimentary tract increases nearly three-fold during the 4 or 5 days of transformation from the acronurus to the juvenile form, reflecting a change in food habits from feeding on zooplankton to feeding on algae. The length of the gut increases from about three times the standard length in small juveniles to nearly six times in large adults.

13. Algae passed through the gut of juvenile manini in 1 hr. 45 min. and in about 2 hr. in adults. At night when feeding ceases, the gut is emptied slowly.

14. Although sustaining growth, the *Enteromorpha* appeared little affected after passing through the gut of manini. Additional work is needed to determine what is utilized by the manini from its algal food.

15. The stomach of the manini varies from slightly acidic to slightly alkaline. The intestine is alkaline (pH 7.7 to 9.1) and the gall bladder acidic (pH 6.2 to 6.4).

Amylase was detected throughout the digestive tract, strongest in the pancreas and weakest in the stomach. The pH optimum of the amylase is about 6.7. Maltase was not found.

Lipase, with a pH optimum of 7.2, was found in all digestive organs, strongest in the pancreas and pyloric caeca and weakest in the stomach.

Proteolytic enzymes are weak, especially from the stomach; pH optimum of pancreatic protease is about 8.4.

16. About two-thirds of the adult manini caught in unbaited traps off Oahu in from 30 to 90 ft. are males. Of 221 manini in museum collections from the tropical Pacific mostly taken from inshore waters, 134 (60.7 per cent) are females.

17. Although ripe males may be taken throughout the year (fewer, however, in the fall), ripe female manini have been found in Hawaii only from early December to late July (and transforming young from middle February to early October). Average monthly sea surface tempera-

tures in the Hawaiian Islands vary from about 75° to 81° F. Enlargement of the gonads appears to coincide with decreasing water temperature in the fall.

18. An estimate of about 2½ months for the duration of larval life of the manini in Hawaii was made by noting the time between the finding of the first ripe females and first transforming young of the season and the last ripe fish and last incoming acronuri.

19. Ripe female manini (*Acanthurus triostegus triostegus*) were found in collections made at islands of the tropical Pacific (where mean sea surface temperatures exceed 80° F. throughout the year) in all months of the year, as were transforming or early juvenile specimens, thus indicating year-round spawning in more equatorial waters.

20. A lunar periodicity in the number of transforming manini was discovered from tidepool collections on Oahu, with the peak in spring occurring a few days before new moon. Since a collection of young from the Gilbert Islands, where water temperatures average about 7° F. higher (and hence development is probably more rapid), indicates peak influx of acronuri approximately at the time of full moon, the periodicity is not attributed to any lunar effect on the young but to greater spawning by adults at one time of the month than another. Thirty-nine ripe female fish were found among 2,552 adult manini examined from 12 days before to 2 days after full moon during the spawning season and 4 among 1,311 fish seen in the remaining half of the lunar month.

21. Individual manini appear to spawn more than once during the season. Large and small ripe females were found near the start and end of the season. No completely spent ovaries were observed until July and August. In graphs of egg diameters of mature ovaries, a mode of egg size about intermediate to the diameter of transparent ripe eggs and primordial ova was invariably present during the season.

No specimens were found with modes of egg size lying between the intermediate-size mode and that of fertilizable eggs, thus suggesting that ripe eggs develop rapidly from the opaque ova of the intermediate group.

22. Although the spawning of manini was never witnessed in the Hawaiian Islands, *A. triostegus triostegus* was observed to spawn in the Tuamotu Archipelago. Several hundred fish were seen in a milling aggregation at dusk during the time of full moon. Many had broader bars on the body and darker fins than normal; 5 of these were speared and proved to be ripe males. Two normally colored manini were females, 1 running ripe. Spawning occurred at the apex of sudden rapid upward movements by small groups of fish. A current carried the eggs to the open sea.

23. The smallest running ripe female manini which was found on Oahu was 101 mm. in standard length; the smallest male, 97 mm. Manini probably do not spawn in their first year.

24. The number of ripe eggs in the ovary of one 123 mm. manini was estimated at 40,000.

25. Early development was studied following artificial fertilization of the eggs. The eggs average 0.67 mm. in diameter, have a single oil globule, and float at the surface. Hatching occurs in 26 hr. at 24° C. As yolk is used up, the larvae show a progressive tendency to sink. They combat this by upward swimming movements. Feeding begins at the age of 5½ days. No young were maintained in aquaria more than 6½ days; however, 3 postlarval manini, 6.6 to 7 mm. in total length, could be identified from plankton collections by fin-ray counts. The most striking feature of their morphology is very elongate second dorsal, second anal, and pelvic spines.

26. Manini acronuri come into shoal water to transform only at night. They are discoid, scaleless, and transparent with a silvery abdomen. Their second dorsal, second anal, and pelvic spines are poisonous. During transformation, which requires 4–5 days, adult-type configuration and coloration is attained, scales form, and the venomous quality of the spines disappears.

27. Light appears to be essential to transformation. Two acronuri taken at midnight were placed in a darkened 2½ gal. battery jar. They failed to transform, whereas 3 others in a comparable but not darkened container completed their metamorphosis to juvenile form.

28. A variation in standard length from 22 to 29.5 mm. was noted in 175 manini acronuri from Oahu in their first day of transformation. One hundred and sixteen were collected in tide

pools from 5 days before to 5 days after peak tide-pool recruitment (2 days before new moon). When the lengths of these manini were compared with the lengths of the 59 acronuri from the rest of the lunar month, a smaller range of length (23.5–28.5 mm.) was apparent for the former group in spite of nearly twice as many specimens. Presumably individual acronuri are capable of transforming some days before the rest of their age group, and hence at a smaller size, when they come inshore earlier than the others. Similarly, those which reach shoal waters later than the majority will have attained larger than average size.

29. A variation in size at transformation was found with locality which appears related to water temperature. The smallest size occurs in the warmest regions (about 20 mm. in the East Indies) and the largest in cooler sectors (Phoenix Islands excepted).

In the Hawaiian Islands the size at transformation averaged 26.3 mm. for 39 specimens collected in April and May and 25.4 mm. for 38 specimens which were taken from July to October (thus developing during warmer months).

30. Growth of juvenile manini, as determined by rearing of captive fish, recovery of fish marked by clipping rays from the top or bottom of the caudal fin, and progression of modes in successive graphs of tide-pool collections on Oahu is about 12 mm. per month.

The recovery of 281 manini of 1,247 tagged with Petersen disk tags fastened with monofilament nylon provided information on the growth of larger fish. The growth of adults 100 to 120 mm. in standard length is slightly greater than 1 mm. per month; 120 to 141 mm. fish grow about 0.8 mm. per month.

Growth of both juveniles and adults ceases during the winter months in the Hawaiian Islands.

31. No annular marks could be detected on the scales, otoliths or vertebrae of manini from which estimates of age could be made. Two larger acanthurids, *Naso unicornis* and *Acanthurus xanthopterus*, lived 20 and 15 years respectively in the Waikiki Aquarium in Honolulu where they died as the result of accidents.

32. Small juvenile manini tend to remain in the tide pool or shallow water area to which they first come as acronuri. With increasing size they move seaward.

Locality data from the recovery of tagged adult manini was too general to determine local movements, but adequate to demonstrate that no extensive migrations are normally undertaken by this surgeonfish. If displaced from their home area, however, manini are capable of wandering distances as great as 8 mi.

33. Manini may be seen as solitary fish, in small groups, or in large feeding aggregations. One large group of fish, although observed to remain in one region in the Tuamotus, moved as much as 300 yd. in several hours.

34. Juvenile manini in a large tide pool on Oahu were observed to have two hiding places beneath ledges, one of which was preferred. In order to attain shelter they will swim toward an intruder, if necessary. From 4 to 7 hr. were required for aquarium fish to accept an inverted bowl tilted on edge as shelter.

Adults are less inclined to seek shelter. Their reaction to an approaching swimmer usually takes the form of retreat.

35. Juvenile manini frequently fight among themselves, both in the natural environment and after being adapted to aquarium life. This does not concern territoriality, but is an expression of dominance by larger fish over smaller fish or old residents (in the case of aquarium fish) over new arrivals. A distinct color change, which involves an almost complete reversal of color pattern, is readily apparent, with the more aggressive fish becoming the darkest. Generally there is no contact between fish, and the fish under attack usually retreat. If not, there is a circling at close quarters with occasional overt movements, especially with the posterior part of the body. The manini's caudal spine is small, and the juveniles were observed to inflict at most only superficial scratches.

Manini were not observed to fight with other species but they may display a dominance in their behavior towards some.

36. With the onset of darkness juvenile and adult manini settle to the bottom, usually with pelvic and anal fins in contact, and enter a state of torpor or sleep. Occasional short movements are made, these more often directed backward than forward. Even when remaining in one place

the pectoral fins are kept in slow motion and there are vertical undulations of the median fins. The color is darker than during the day, and large dark blotches are conspicuous between the vertical black bars on the body. A period of 25 min. after darkness ensued was found to be necessary for the fish to reach a state when they could be lightly touched without fleeing. When lights were kept on in an aquarium for 24 hr., manini remained active, however they ceased to feed toward the end of this period and swam restlessly. A light was turned on after 10 manini, 27 to 40 mm. in standard length, were allowed to sleep for 3 hr. From 13 to 28 min. were required for the fish to awaken, the smallest taking the longest time.

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A New Species of *Micronereis* (Annelida, Polychaeta) from the Marshall Islands[1]

DONALD J. REISH[2]

DURING THE COURSE of surveying Eniwetok Atoll, Marshall Islands, for polychaetous annelids in the summers of 1957 and 1958, the author encountered from three localities four specimens of a new species of polychaete belonging to the nereid genus *Micronereis* Claparède. Transects were made of both the ocean and lagoon sides of the islands shown in the map of Eniwetok Atoll (Fig. 1). One of the collecting methods employed was to preserve algae, coral, rocks, sand, etc., in formalin in the field and to sort out the polychaetes in the laboratory. The new species of *Micronereis* was collected in this manner.

FAMILY NEREIDAE

Micronereis Claparède

Micronereis eniwetokensis n. sp.
Figs. 2–6

Four complete specimens, each with 17 setigerous segments measuring 1.5 to 2.0 mm. in length, came from three localities in Eniwetok Atoll. The prostomium (Fig. 2) is broadest posteriorly and is clearly separated from the first setigerous segment. The prostomium is weakly indented at its anterior margin. Four pairs of tentacular cirri are broadest near the point of attachment and tapered distally. The short palpi are viewed from the ventral side. There are no prostomial tentacles or peristomium as is characteristic for the genus.

Four large eyes are in trapezoidal arrangement, with the anterior pair being the larger, farther apart, and provided with a clear lens. A variation was noted in the eyes of one specimen (Fig. 3). The anterior pair was elongated and extended posteriorly and laterally to the second pair. Each anterior eye was provided with a large clear lens.

The yellow jaws (Fig. 4) were seen by dissection or by mounting the worm in glycerine. They were broadest at their base and terminated in one large tooth and three smaller teeth. The apical tooth was serrated along its inner margin.

The first two setigerous segments are uniramous with homogomph spinigers. Each has a filiform ventral cirrus.

All parapodia (Fig. 5) are biramous from the third setigerous segment to the posterior end. The rami are widely separated and each has a single black aciculum. The inner margin between the notopodium and neuropodium is ciliated. Each ramus has a cirrus; the dorsal one is longer than the ventral one.

All setae (Fig. 6) are homogomph spinigers with the appendages lacking spines along their margins. The setae number 12–20 in each lobe of the parapodium.

The pygidium is characterized by having a bilobed ventral fleshy membrane and two blunt lateral lobes.

DISCUSSION

Three species are previously known for the genus *Micronereis*, *M. variegata* Claparède 1863, *M. nanaimoensis* Berkeley and Berkeley 1953, and *M. halei* Hartman 1954. Sexual dimorphism has been described for the former two species. Specialized setae in the third setigerous segment of the male, and a difference in the number of segments between the two sexes, occur in both *M. variegata* and *M. nanaimoensis*. The jaws vary according to sex in *M. variegata*. Additional dimorphic characters in *M. nanaimoensis* include the pygidium, coloration, and capillary setae in

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the male. Sexual dimorphism is unknown for *M. halei* and *M. eniwetokensis*.

The large anterior eyes (Fig. 3) on one individual of *M. eniwetokensis* are an unusual variation for the members of the genus. The appearance of secondary sex characteristics, such as enlargement of the eyes prior to sexual maturity, is widespread in the family Nereidae (Reish, 1957), but it is unknown for the genus *Micronereis* (Berkeley and Berkeley, 1953; Rullier, 1954). No other morphological differences were noted in this specimen collected from 94 ft. of water in the lagoon.

M. eniwetokensis comes closest to *M. varie-*

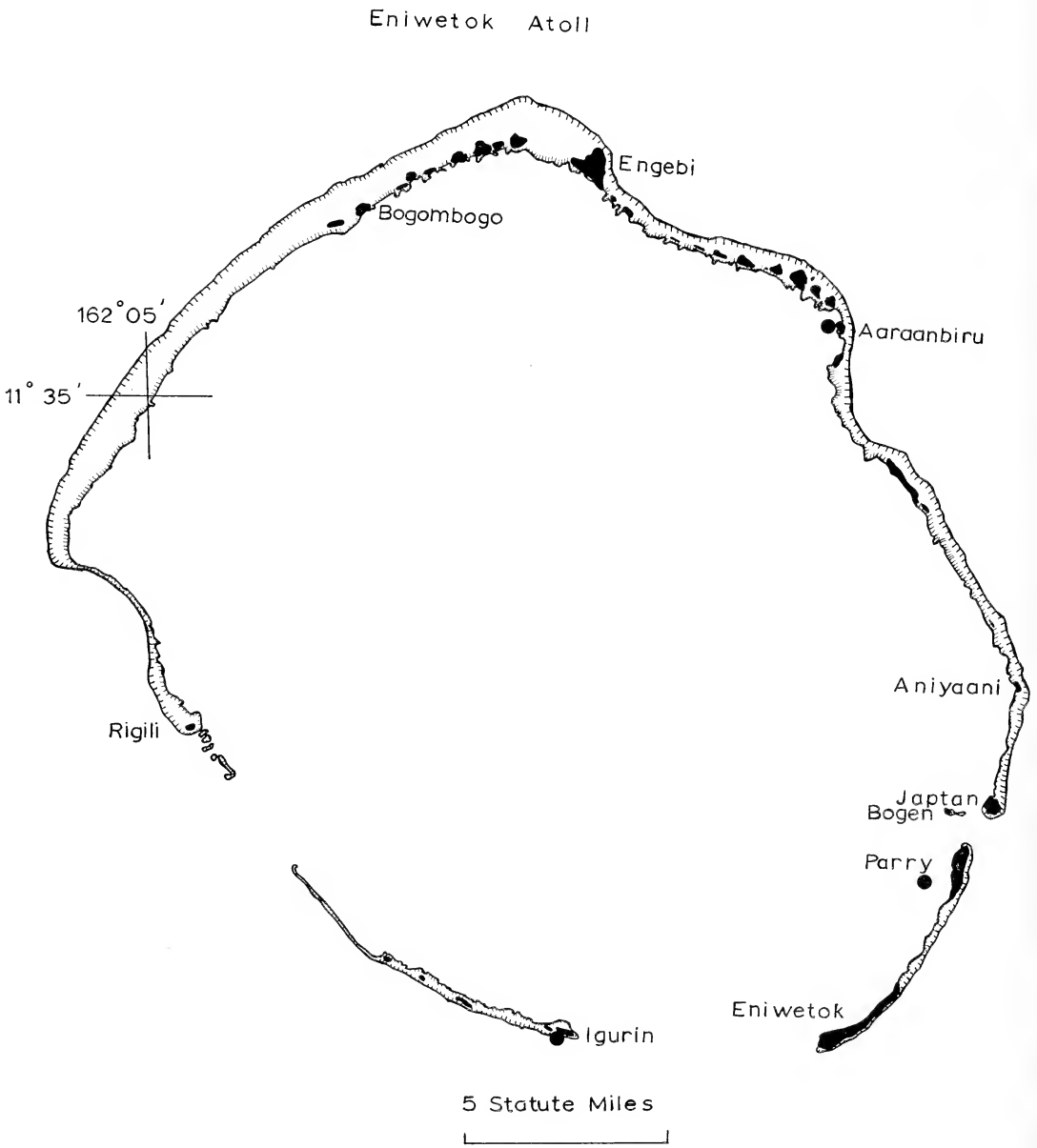
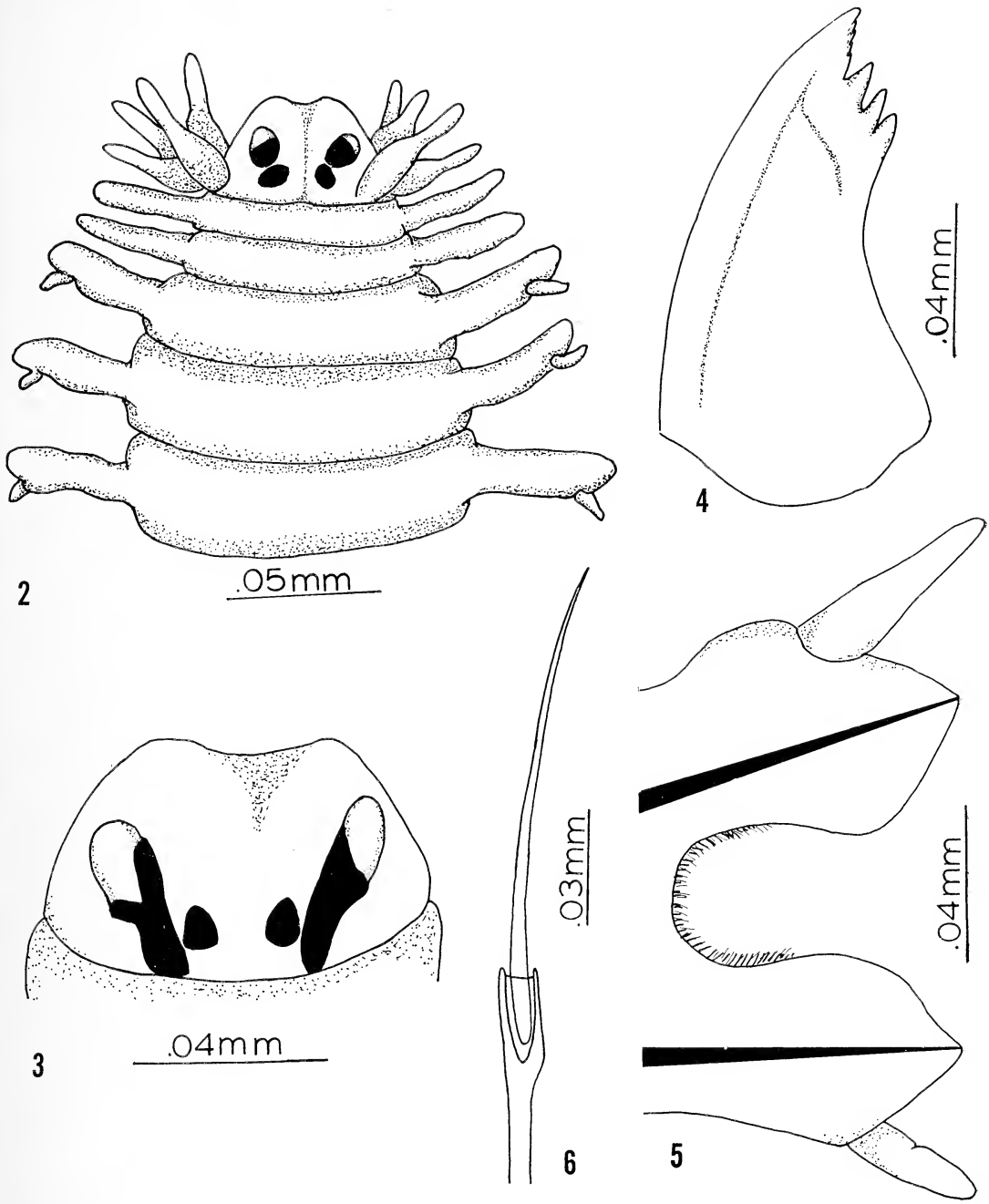


FIG. 1. Map of Eniwetok Atoll, Marshall Islands. Collections were made at the named islands. *Micronereis eniwetokensis* was collected from the areas indicated by the dots.



FIGS. 2–6: 2, Anterior end of the holotype of *Micronereis eniwetokensis;* 3, prostomium of *M. eniwetokensis* with enlarged eyes; specimen collected from a depth of 94 ft. in the lagoon of Eniwetok Atoll; 4, jaw of *M. eniwetokensis;* 5, parapodium from the mid-region of *M. eniwetokensis;* setae omitted from figure; 6, homogomph spiniger from the notopodium of Figure 5.

gata; they differ in the nature of the homogomph spiniger, the pygidium, and the presence or absence of cilia on the parapodia. There are some distinct characteristics for the male of *M. variegata*; it is not known whether or not sexual dimorphism occurs in *M. eniwetokensis*. The diagnostic characters for the known species of the genus are summarized in Table 1.

TYPE MATERIAL: The holotype, one paratype, and two additional specimens have been deposited in the U. S. National Museum.

TYPE LOCALITY: Intertidal region on the lagoon side of Aaraanbiru Island, Eniwetok Atoll, Marshall Islands (Fig. 1).

ECOLOGY: As stated above, pieces of coral rock of loose substrate were preserved in the field at each station visited. *M. eniwetokensis* was collected in this manner. It was associated with the following species of polychaetes:

Aaraanbiru Island, lagoon side, substrate coral rock and beach rock with algae attached. Polychaetes: *M. eniwetokensis* (2 specimens), *Haplosyllis spongicola* Grube (1), *Opistosyllis longicirrata* Monro (6), *Ceratonereis mirabilis* Kinberg (17), *Eunice afra* Peters (1), *Lysidice collaris* Grube (3), *Palola siciliensis* Grube (3), *Dodecaceria laddi* Hartman (2), and *Polyophthalmus pictus* (Dujardin) (19).

Igurin Island, ocean side, substrate coral rock and fragments taken from under coral head near surge zone. Polychaetes: *Micronereis eniwetokensis* (1 specimen), *Eurythoë complanata*

TABLE 1

COMPARISONS OF THE KNOWN SPECIES OF *Micronereis*

CHARACTERISTIC	*M. variegata*	*M. nanaimoensis*	*M. halei*	*M. eniwetokensis*
Length	2–4 mm.	13–15 mm.	7 mm.	1.5–2.0 mm.
Number of setigerous segments				
♂	17–18	23	20–25	17
♀	21	26	(sex unknown)	(sex unknown)
Palpi	absent	present	present	present
Jaws	dimorphic; ♂ 5 teeth ♀ 4 teeth	4–5 teeth	6 teeth	4 teeth
Crotchets in ♂, taird segment	2 curved	5+ crested	unknown	unknown
Spines on appendage of homogomph spinigers	present	present	absent	absent
Cilia on parapodia	absent	present	absent	present
Pygidium	2 anal cirri	2 anal cirri in ♂ and ♀; also 2 lateral lobes in ♂	——	2 lateral lobes; ventral bilobed membrane
Unique pigmentation	none	2 red bands on tentacular cirri; see original account for body pigmentation	brown band on tentacular cirri	none
Unique characters	none	capillary setae in ♂	inferior notopodial and superior neuropodial lobes in parapodium	none
Geographical distribution	Europe, Mediterranean Sea	British Columbia, Canada	South Australia	Eniwetok Atoll, Marshall Islands

(Pallas) (2), *Pseudeurythoë oculifera* (Augener) (1), *Genetyllis gracilis* (Kinberg) (1), *Typosyllis variegata* (Grube) (2), *Platynereis pulchella* Gravier (6), *Lysidice collaris* (1), *Palola siciliensis* (1), *Dodecaceria laddi* (2), and *Terebella ehrenbergi* Grube (1).

Parry Island, lagoon side in 94 ft. of water collected by Mr. Mike Chamberlain, 450 ml. of light gray sand. Polychaetes: *Micronereis eniwetokensis* (1 specimen), *Micronephthys sphaerocirrata* (Wesenberg-Lund) (2), previously known only from the Sea of Iran (Wesenberg-Lund, 1949), and *Scolelepis indica* Fauvel (2).

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Life Cycle of *Mesostephanus appendiculatus* (Ciurea, 1916) Lutz, 1935 (Trematoda: Cyathocotylidae)[1]

W. E. Martin[2]

For a number of years, the author has been studying trematode larvae which develop in the California horn-shell snail, *Cerithidea californica* Haldeman. One of these, a pharyngeate, furcocercous cercaria, proved to be the larva of *Mesostephanus appendiculatus*. The adults of this species were first described from the small intestines of Rumanian cats and dogs by Ciurea (1916). Ciurea, however, placed this species in the genus *Prohemistomum*. Price (1928) found this parasite in the small intestine of a dog that had lived in the vicinity of Washington, D.C. Lutz (1935) transferred this and some other species to his new genus, *Mesostephanus*, naming *M. fajardensis* (Price, 1934) as type species. Dubois (1953) includes the following species in the genus *Mesostephanus*: *M. fajardensis* (Price, 1934); *M. appendiculatus* (Ciurra, 1916); *M. appendiculatoides* (Price, 1934); *M. cubäensis* Allegret, 1941; *M. haliasturis* Tubangui and Masiluñgan, 1941; and *M. longisaccus* Chandler, 1950. Caballero, Grocott, and Zerecero (1954) added *M. microbursa* from the intestine of *Pelecanus occidentalis californicus*. Dubois (1953) believes that the members of the genus are natural parasites of certain fish-eating birds and accidental parasites of dogs.

MATERIAL AND METHODS

Infected *Cerithidea californica* were isolated in finger bowls. Emerged cercariae were studied alive and as fixed and stained whole mounts. Cercariae were fixed without pressure by forcibly ejecting them into cold Bouin's solution. Earlier larval stages and percentages of infection were obtained by crushing snails. Uninfected *Fundulus parvipinnis parvipinnis* (Girard) and *Gillichthys mirabilis* Cooper were collected in an isolated pool where there were no snails. These fish were exposed to cercariae and, following a lapse of 2–3 weeks, were fed to hatchery-raised chicks. The chicks were examined 9 days after the experimental feeding. The adult worms obtained were fixed in Bouin's solution under slight cover-glass pressure. Larval and adult stages were stained with paracarmine and mounted in Permount.

All measurements are in millimeters.

OBSERVATIONS

The sporocysts and cercariae of *Mesostephanus appendiculatus* develop in the digestive gland of the brackish-water snail, *Cerithidea californica*. During a 12-month survey (Martin, 1955), in which at least 1,000 snails were examined each month, only 7 infections of this parasite were found in 12,995 snails.

SPOROCYST (Fig. 2): Mother sporocysts were not observed. Daughter sporocysts are saccular and elongate. Measurements of 20 stained and mounted specimens are: length 1.368–3.355, av. 2.38; maximum width 0.173–.302, av. 0.236. The wall of the sporocyst has transverse contractile bands. At intervals there are thicker bands which give a false appearance of segmentation. One end of the sporocyst has a thick wall which is traversed by a birth canal.

CERCARIA (Figs. 3, 4): The cercariae are nonoculate and furcocercous. Though they lack eyespots, they show positive phototropism. The body surface is covered with minute, quincuncially arranged spines and scattered papillae

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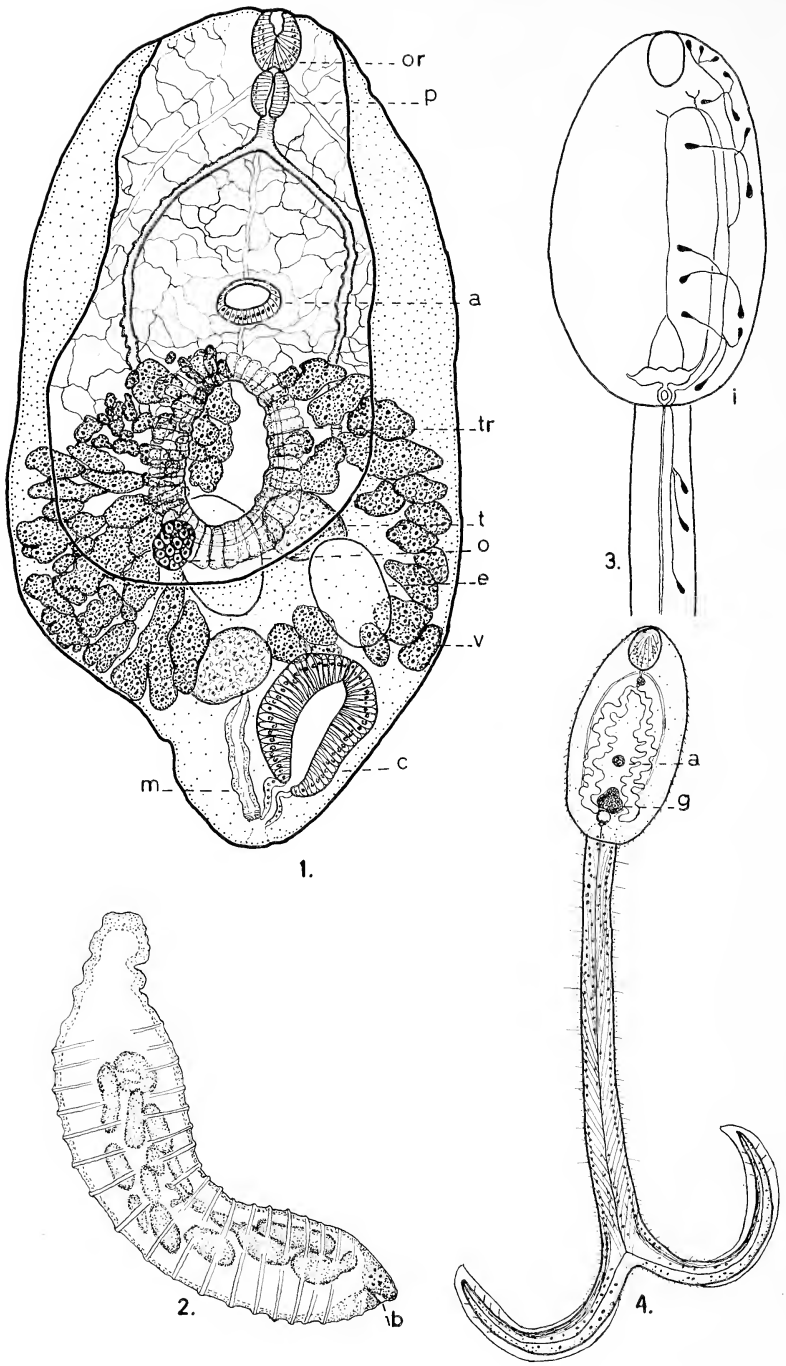
with bristles. Tubular glands are plentiful laterally and sparse dorsoventrally in the anterior half of the body. Ten to 12 glands have their cell bodies near the oral sucker and have ducts opening near the mouth. Measurements based on 20 stained and mounted specimens are: body length 0.18–.258, av. 0.192; maximum body width 0.078–.115, av. 0.094; oral sucker length 0.031–.045, av. 0.038; oral sucker width 0.025–.037, av. 0.03; ventral sucker midventral, rudimentary, 0.009–.012, av. 0.01 in diameter; lengths of prepharynx and esophagus approximate that of pharynx; pharynx oval to spherical, 0.006–.012, av. 0.011 long and 0.012–.016, av. 0.013 wide; intestinal caeca sinuous, terminating near excretory bladder; genital primordium median, immediately anterior to excretory bladder, 0.006–.022, av. 0.019 long and 0.019–.025, av. 0.021 wide; excretory bladder small, transversely elongate, with exit duct entering tail, dividing into two ducts which pass around the "Island of Cort" and rejoin, extending to the furcal region to divide into two ducts, each of which opens to the outside at the tip of a furca. Four collecting ducts empty into the bladder, two laterally and two medial to the lateral ducts on the anterior wall of the bladder. The two medial ducts pass around the genital primordium to unite and proceed as a single duct to a point near the bifurcation of the gut where it joins the lateral ducts which have proceeded anteriorly from the bladder. As the lateral ducts bend medially, each gives off a duct whose proximal portion contains a tuft of cilia. The latter duct extends posteriorly to about mid-body level where it divides into anterior and posterior branches each of which collects from three groups of three flame cells each. Three of the flame cells emptying into the posterior branch are located in the tail. The excretory formula is $2\ [(3+3+3)\ +\ (3+3+(3)] = 36$. Short, moniliform concretions occur in the main collecting tubes. The tail is set in a dorsal socket near the posterior end of the body. The tail surface bears bristles and minute spines. The tail stem length is 0.358–.407, av. 0.376, and maximum width near the junction with furcae 0.014–.022, av. 0.021. The furcae are 0.18–.2, av. 0.19 long and 0.019–.022, av. 0.021 in maximum width near the junction with the tail stem. Each furca bears a dorsoventral fin over the distal four-fifths of its length.

METACERCARIA: *Fundulus parvipinnis parvipinnis* and *Gillichthys mirabilis* were exposed to cercariae which rapidly penetrated the skeletal muscles and encysted. Penetration of large numbers of cercariae killed the fish. Death of the second intermediate host due to the penetration of large numbers of cercariae has been noted by Vernberg (1952) for a related parasite. Metacercariae approximately 3 weeks old were dissected from the fish and were fed, along with some muscle tissue, to hatchery-raised chicks.

ADULT (Fig. 1): Adult *Mesostephanus appendiculatus* were obtained from the small intestines of hatchery-raised chicks fed fish muscle and metacercariae. The chicks were examined 9 days after the experimental feeding. The following description and measurements are based on nine specimens. Body surface covered with scale-like spines arranged quincuncially. Body length 0.547–.763, av. 0.68; body width 0.346–.518, av. 0.41; oral sucker length 0.04–.059, av. 0.049; oral sucker width 0.047–.078, av. 0.055; acetabulum 0.04–.068, av. 0.06 in diameter; tribocytic organ well developed, opening usually slitlike; prepharynx very short; pharynx 0.037–.058, av. 0.05 long and 0.031–.044, av. 0.037 wide; esophagus approximately one-half pharyngeal length, with transverse muscle fibers; intestinal caeca sinuous, with occasional short diverticula, reaching to near posterior end of body; testes oblique, in posterior half of body, 0.109–.124, av. 0.116 long and 0.072–.087, av. 0.079 wide; cirrus sac and cirrus well developed; male genital opening communicates with common genital exit at posterior end of body; ovary intertesticular, 0.05–.08, av. 0.065 long and 0.04–.065, av. 0.05 wide; metraterm elongate, muscular, with sphincter at distal end where it empties into common genital exit; eggs yellow, operculate, 0.084–.137, av. 0.108 long and 0.058–.081, av. 0.07 wide; vitellaria composed of discrete follicles arranged in a circle in posterior half of body but not entering posterior conical body extension; excretory system more complex than in cercaria, anastomosing branches arise from main collecting ducts, some branches end blindly near body surface.



FIGS. 1–4: 1, Adult *Mesostephanus appendiculatus,* ventral view; 2, sporocyst; 3, diagram to show most of excretory system; 4, cercaria, ventral view. Abbreviations: *a,* Acetabulum; *b,* birth pore; *c,* cirrus sac; *e,* egg; *g,* genital primordium; *i,* Island of Cort; *m,* metraterm; *o,* ovary, or oral sucker; *p,* pharynx; *t,* testis; *tr,* tribocytic organ; *v,* vitellaria. All drawings made with the aid of a camera lucida unless otherwise stated.

DISCUSSION

The body dimensions of the adult *M. appendiculatus* described in this paper are smaller than those listed for the species by Dubois (1938). This may be due to the fact that the duration of the infection was only 9 days so that the worms probably had not attained their full size even though they were sexually mature. The range of egg size and the number of eggs (1–7) in the uterus were greater in my specimens that in those listed by Dubois (1938), which include measurements given by Ciurea (1916) and Prendel (1930). The anterior extent of the cirrus was greater in some specimens than is shown in Figure 1. The extent of the cirrus in Figure 1 resembles that of *M. microbursa* Caballero, Grocott, and Zerecero (1954), recovered from the intestines of pelicans, *Pelecanus occidentalis californicus,* collected in Panama and in the Coronado Islands off Mexico. However, the sucker ratio, spination, and extent of the posterior appendix are different in the two species.

The present work extends the range of *M. appendiculatus* to the west coast of the United States. It has been found on the east coast of this country by Price (1928), in Rumania by Ciurea (1916), and in the Ukraine by Prendel (1930).

Dubois (1953) states that pelicans are the natural hosts of this species. Since this parasite can develop also in dogs, cats, and chicks, the present author believes that other fish-eating birds probably serve as additional natural hosts.

Maxon and Pequegnat (1949) examined *Cerithidea californica* collected at Newport Bay, California, between October, 1947, and May, 1949. They found 21 per cent of the snails infected with furcocercous cercariae. They described one of the latter with 16 flame cells but did not describe the cercaria of *Mesostephanus appendiculatus.*

SUMMARY

The life cycle of *Mesostephanus appendiculatus* (Ciurea, 1916) Lutz, 1935 has been demonstrated experimentally. Sporocysts and cercariae develop in the brackish-water snail, *Cerithidea californica* Haldeman, collected at Newport Bay, California. The cercaria is furcocercous and has a flame-cell pattern expressed by the formula 2 [(3+3+3) + (3+3+(3)] = 36. Second intermediate hosts are *Fundulus parvipinnis parvipinnis* (Girard) and *Gillichthys mirabilis* Cooper. Experimentally infected fish were fed to hatchery-raised chicks. After a lapse of 9 days, egg-bearing worms were removed from the small intestines of the chicks.

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Some Notes on the Hawaiian Monk Seal

JUDITH E. KING[1] and R. J. HARRISON[2]

UP TO 1958 the collections of the British Museum (Natural History) possessed neither skeletal material nor skin of the Hawaiian or Laysan monk seal, *Monachus schauinslandi* Matschie 1905. Indeed the only remains of this animal in Europe until now have been those brought back by Dr. Schauinsland, amongst which was the skull of the seal later named after him by Matschie (Matschie, 1905). The stuffed skin of this animal is in the Bremen Museum and the type skull is in the Zoological Museum in Berlin, no. 32795 (Wahlert, 1956). So it was with great pleasure that we received, in the summer of 1958, through the kindness of Mr. Vernon E. Brock, then director of the Territorial Division of Fish and Game, Honolulu, Hawaii, a young male monk seal from Laysan Island that had been shipped complete and frozen to this country. The animal was thawed, injected with coloured gelatin in the vascular system, and dissected after fixation, but unfortunately the tissues were too poorly preserved for any accurate histology.

DESCRIPTION

The seal is young, has a nose-to-tail length of 163.5 cm. (5 ft. 6 in.) and weighs 74.4 kg. (164 lb.) complete. Kenyon and Rice (1959) give the estimated weights of recently weaned pups as from 95–160 lb. The present animal was caught June 4, 1958, and as it must have been very near to being weaned, its probable date of birth must have been about April 30. Although the weight is a little high for a recently weaned pup, the animal is in very good condition and is unlikely to have been a yearling, as yearlings are relatively thin and do not reach the weight and condition of pups that have been feeding from their mothers. Similarly the state of the epiphyses and the obvious youth of the skeleton make it unlikely that it is from a 2-year-old animal. The age of the present animal is therefore estimated to be about 5 weeks (the thymus is large and weighs 32.5 g.). The coat is dark silvery grey dorsally, on the top of the head, on both sides of the fore and hind flippers, and on the dorsal surface of the tail. Laterally the grey shades to silvery white ventrally. The hind flippers are a little lighter grey on the inner side towards their insertion. There are also lighter patches round the eyes and surrounding the insertion of the supraorbital vibrissae, and along the upper lip. The lower jaw is light in colour. On the back the hairs are dark grey with a white tip. This white tip becomes longer towards the belly so that the ventral hairs are white with a short dark base. The moustachial whiskers are in five rows on each side of the nose, the upper row having four whiskers and the other rows approximately nine in each. The whiskers are dark brown at the base, shading to straw colour at the tip; they are oval in cross section and are not beaded as in *Phoca* (Fig. 1).

The tongue has a notch in its anterior end. The length of the small intestine is approximately 57 ft. The only food remains in the stomach are fish bones and skin and these have been identified as being most probably from the puffer fish, *Arothron meleagris* (Lac.), which is a poor swimmer usually found near coral formations. Nematodes, a small cephalopod beak, and an isopod are also present in the stomach. The nematodes have been identified as *Contracaecum turgidum,* a species previously described from this seal, and the isopod as *Livoneca* sp., usually found as an ectoparasite on fish and probably ingested attached to a fish. In the small intestine there are remains of a tapeworm. It is not in a sufficiently good condition to be identified exactly, but is probably *Diphyllobothrium* sp.

The skin and skeleton of this seal are in the collections of the British Museum (Natural History), the registered number of the skin being 58.521, and that of the skeleton 1958.11.26.1.

OSTEOLOGY

The skeleton of *M. schauinslandi* has not previously been described and although it is attempted here to fill this gap the description and

[1] British Museum (Natural History).

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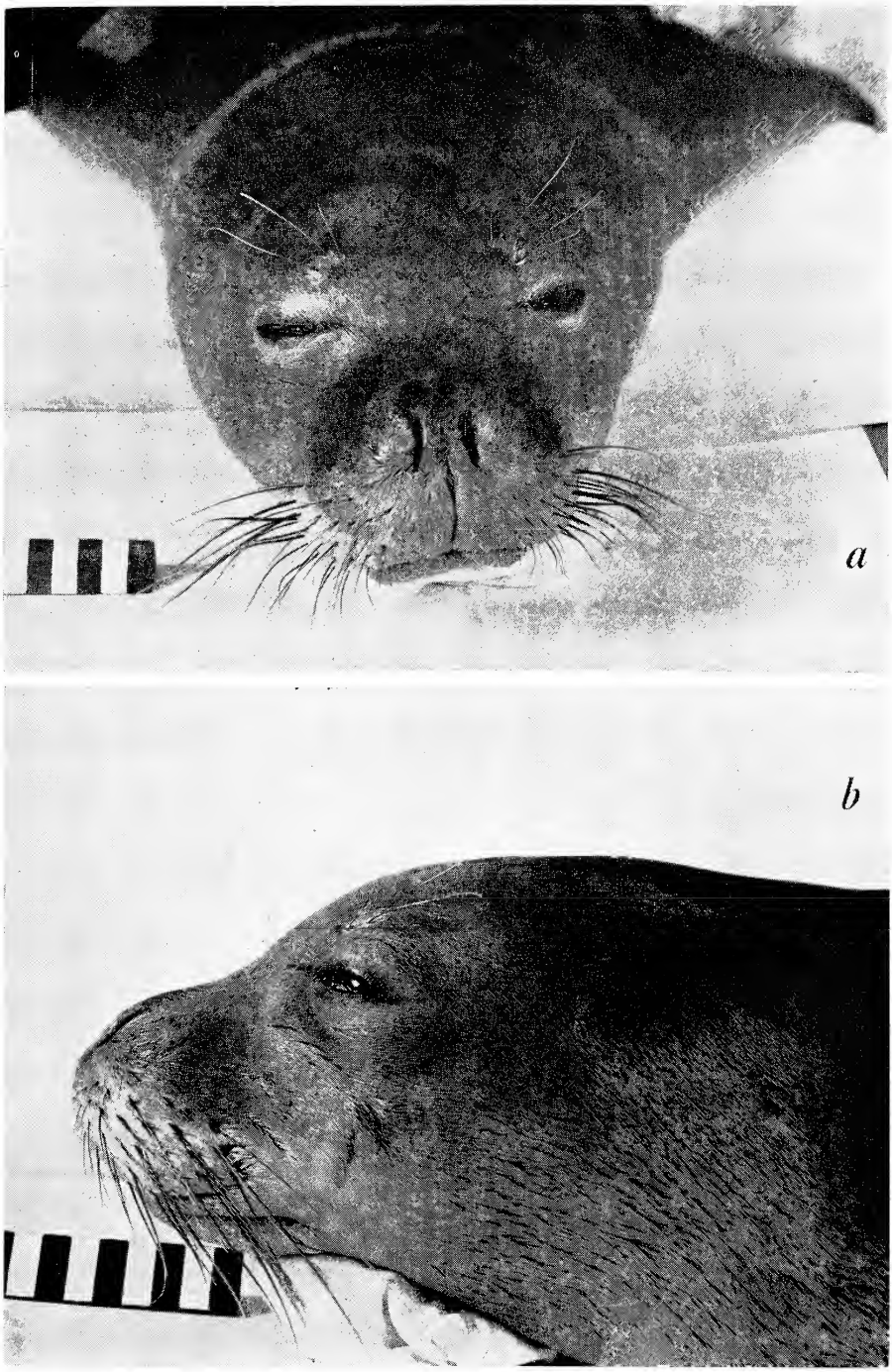

FIG. 1. *a,* Anterior view of the face of *M. schauinslandi. b,* Lateral view of the face, showing dorsal position of nostrils.

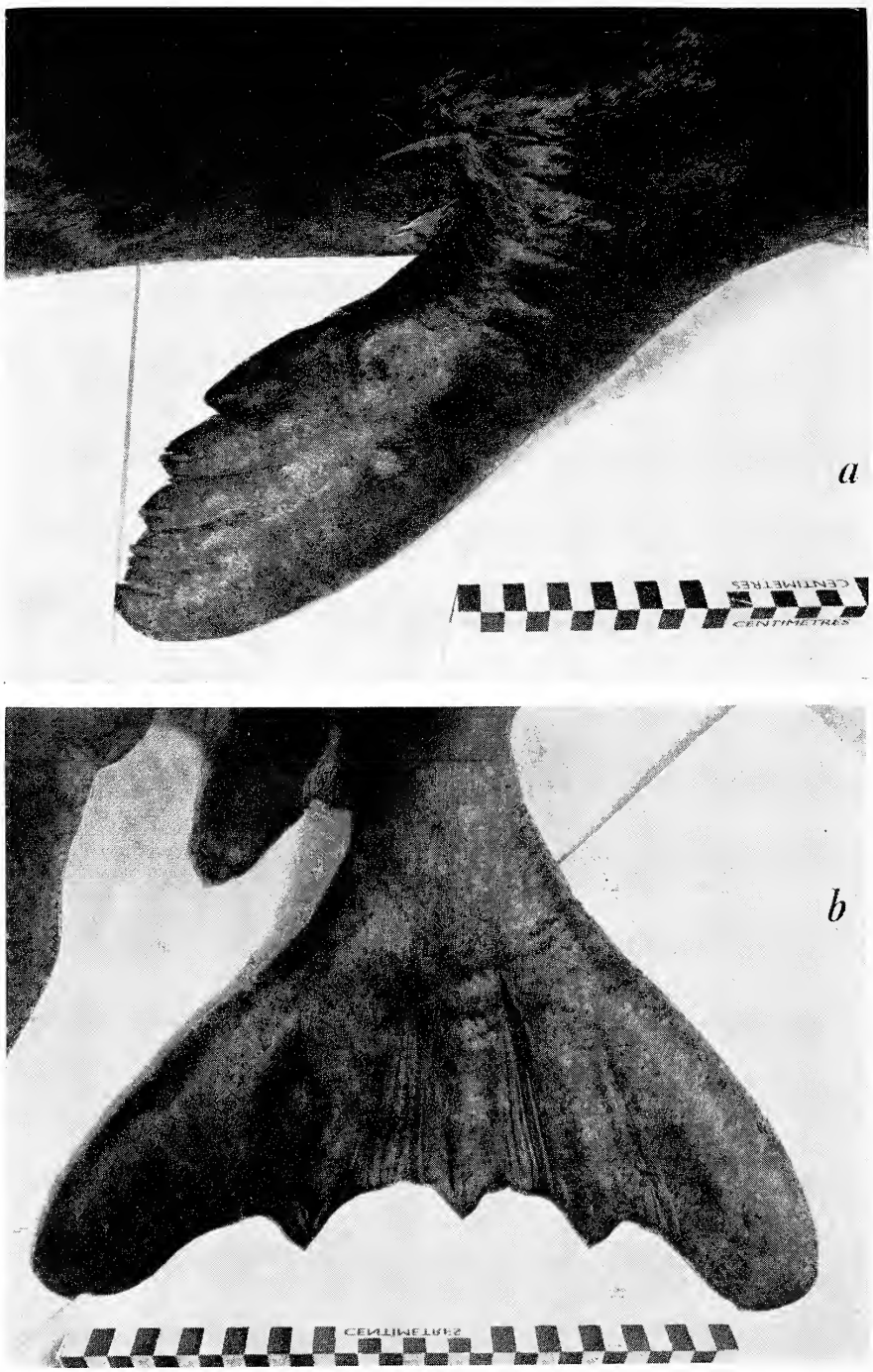

FIG. 2. *a*, Dorsal view of right fore flipper. *b*, Dorsal view of right hind flipper.

comparison are considerably limited by the youth of the specimen. The form of this description is based on that of the skeletons of *M. monachus* and *M. tropicalis* (King, 1956) and frequent reference will be made to the details in that paper. No skeleton of a young *M. tropicalis* was available so the *M. schauinslandi* skeleton was compared with that of an adult *M. tropicalis* (1887.8.5.1.) and of a young *M. monachus* (1894.7.27.3), the skull of which showed by its condylobasal length (224 mm.) and suture age (13) that it was from an animal of approximately the same size as the Laysan monk seal.

Comparison of M. schauinslandi *Skull with Those of* M. monachus *and* M. tropicalis

1. The additional measurements now available of the skull of *M. schauinslandi* confirm the previous statement (King, 1956) that skulls of both *M. schauinslandi* and *M. tropicalis* are slightly narrower in proportion to their width than those of *M. monachus,* though the accuracy of this conclusion is limited by the small number of skulls available.

	M. monachus	*M. tropicalis*	*M. schauinslandi*
	%	%	%
Zygomatic width	59.9–70.3	61.7–62.1	60.9–61.5
Snout width at canines	20.9–26.0	20.6–20.9	20.3–20.5
Width at external auditory meatus	53.1–58.5	49.8–50.5	50.5–55.0
Width at petrous bones	60.3–64.9	56.3–59.2	59.2–64.1

2. The nasal bones of this young animal are as previously described from the type skull. The anterior ends are in the form of an inverted V with the point directed posteriorly; the posterior ends do not taper as much as in *M. tropicalis.*

3. The lower edge of the infraorbital foramen is, when seen from the front, narrower than the upper edge. This confirms Matschie (1905) and is similar to *M. tropicalis.*

4. The absence of a maxillary tubercle at the anterior edge of the orbit also confirms Matschie.

5. As previously noted, the shape of the zygomatic arch is more like that of *M. monachus* than *M. tropicalis.*

6. It was noted previously that the posterior edge of the palate of *M. schauinslandi* formed a wide V. It is now felt that it is better described as U in shape and rather more like that of *M. monachus,* though there is probably a certain amount of variation in this character.

7. The pterygoid bones curve outwards as in *M. tropicalis* and in this young skull of *M. schauinslandi* they are just visible when it is viewed dorsally.

8. The coronoid process of the lower jaw is narrow and like that of *M. tropicalis.*

9. Examination and comparison of the young skull of *M. schauinslandi* now available confirms the previous report that it is more like *M. tropicalis* than *M. monachus* (Fig. 3). There are no supernumerary bones in the skull.

Kenyon and Rice (1959) note that, in the few skulls of *M. schauinslandi* they examined, the shape of the palate and the shape of the zygomatic branch of the squamosal do not appear to be constant and are thus not good distinguishing characters. It is certainly agreed that the shape of the palate is variable and there is a need for the examination of as many adult skulls as possible to determine the amount of variation.

Measurements of Skull of M. schauinslandi *1958.11.26.1*

	mm.	%
Condylobasal length	220	100
Condylobasilar length	211	95.9
Basal length	201	91.4
Basilar length	192	87.3
Snout width at canines	45	20.5
Width of skull at front end of last upper molars	59	26.8
Zygomatic width	134	60.9
Width at upper edge auditory meatus	121	55.0
Width at petrous bones (mastoid width)	141	64.1
Palatal length	101	45.9
Palatilar length	92	41.8
Width of occipital condyles	62	28.2
Length of nasal suture	50	22.7
Length of upper molar row	55	25.0

Suture age 13

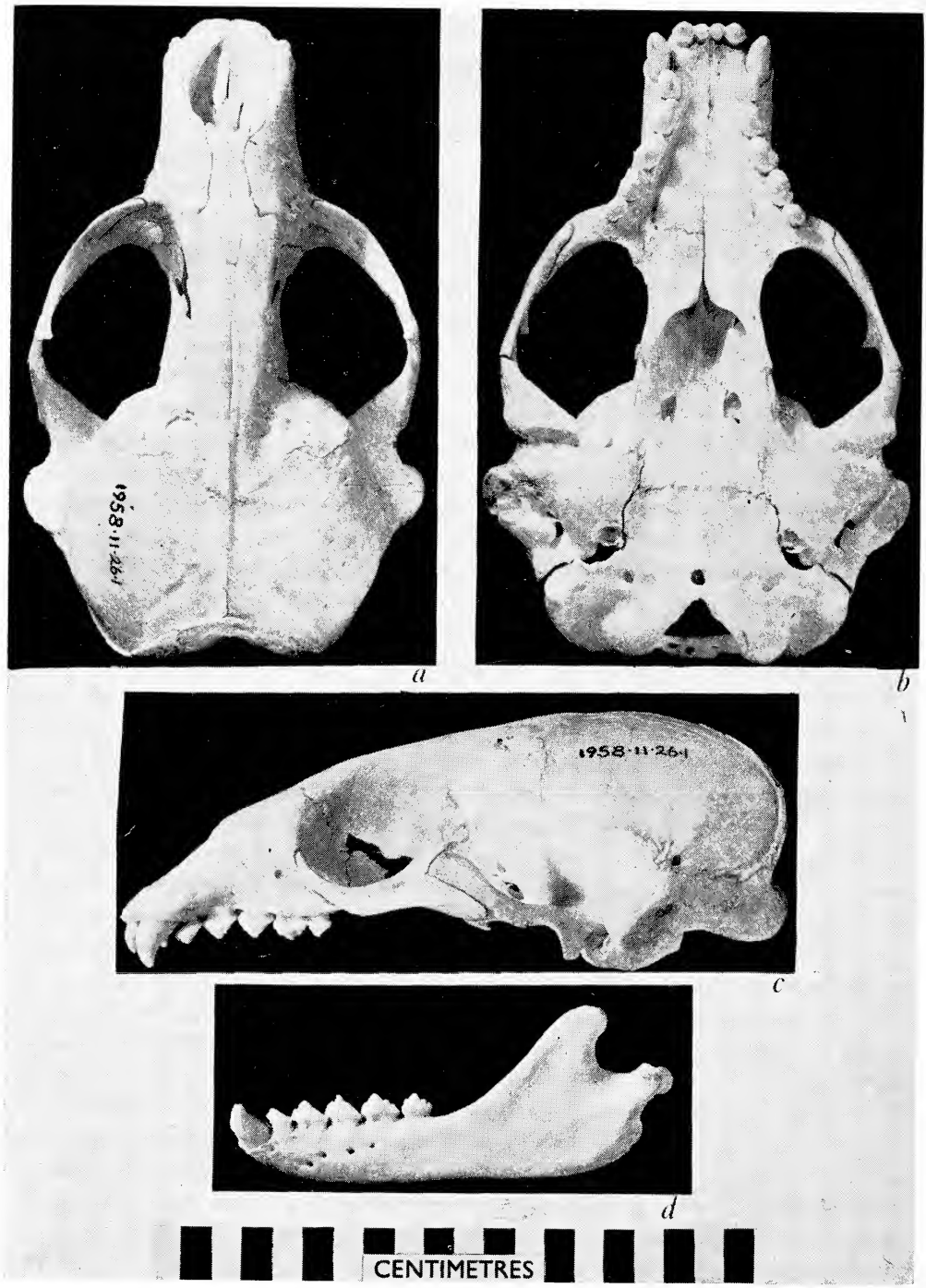

FIG. 3. *a,* Dorsal, *b,* ventral, and, *c,* lateral views of the skull of *M. schauinslandi. d,* Lateral view of lower jaw.

Teeth

Dental formula $\frac{i\ 2}{2}, \frac{c\ 1}{1}, \frac{pc\ 5}{5}$.

The term "post canines" is used here instead of "molars" and "premolars," as these latter cannot be used precisely when referring to pinniped teeth.

UPPER JAW TEETH: As previously mentioned, the upper incisors are set in a straight line across the anterior end of the premaxillae and in general the setting and shape of the teeth are like *M. tropicalis.* The incisors of this young animal do not have such a pronounced "waist" as those of the adult *M. tropicalis,* but it is more evident than in the young *M. monachus.*

The canines are very small for a male animal. Those of the young *M. monachus,* also a male, whose skull is only 4 mm. longer than that of the young *M. schauinslandi,* are much larger.

	M. monachus	*M. schauinslandi*
Anteroposterior length at crown-root junction	15 mm.	12 mm.
Anterior height of canine (in straight line from crown-root junction to tip)	23 mm.	14 mm.

M. tropicalis also has small canines. The measurements given below of the upper canines of an adult male *M. tropicalis* (1889.11.5.1; condylobasal length 267 mm., suture age 25) are compared with those of an adult male *M. monachus* of approximately similar size (1863.4.1.1; condylobasal length 273 mm., suture age 26).

	M. monachus	*M. tropicalis*
Anteroposterior length	16.5 mm.	11 mm.
Anterior height	27 mm.	est. 17 mm. (v. worn)

The height of the crown of the postcanine teeth in both *M. tropicalis* and *M. schauinslandi* is lower than in *M. monachus* and the main cusp is more rounded. In this respect *M. schauinslandi* is more like *M. tropicalis,* but in the possession of a single anterior and posterior cusp it resembles *M. monachus.* The fourth postcanine has, however, two small anterior cusps and two small posterior cusps. The surface of the teeth is more rugose than in *M. monachus* and the anterior and posterior cusps are very much less distinct, as though it is in process of losing the second posterior cusps of *M. tropicalis.* The postcanine teeth are not set obliquely.

LOWER JAW TEETH: The lower incisors are similar to those of *M. tropicalis,* the canines are small, and the postcanines are similar to those in the upper jaw.

No disease or irregularity in number is present in the teeth of either upper or lower jaws.

Skeleton

SCAPULA: The scapula of *M. schauinslandi* is very like that of *M. tropicalis.* It is similar in the way that the anterior edge is directed almost horizontally forwards from the neck before sweeping round to the dorsal surface. In *M. monachus* the anterior edge is directed forwards and upwards at an angle of approximately 45°. The spine in the young Laysan seal is represented by a low ridge with a well-developed acromion process (Fig. 4*b*).

HUMERUS, RADIUS, ULNA: No real comparison can be made because of the youth of *M. schauinslandi,* though the humerus appears to be slightly more robust than that of *M. monachus* of similar size.

MANUS: Except that the terminal phalanges are not so extensively grooved for claws as in the young *M. monachus,* although the claws themselves are of approximately similar size, the manus is not noticeably different in the three species (Fig. 4*c*).

PELVIS: The pelvis is very similar in shape to that of the young *M. monachus* although it is more mature as there is no sign of the symphysis between ischium and pubis, and the acetabulum is deep and well formed, while in the young *M. monachus* the symphysis is about half fused and the acetabulum is shallow and more obviously immature. The shape of the ischium and pubis is like that of *M. monachus* except that the pubis is possibly slightly more slender. There is no sign of the stout pubis and very narrow ischium posterior to the ischiatic spine as in *M. tropicalis.* The ilium is slightly narrower than in *M. monachus.* There is a large foramen for the obturator nerve just posterior

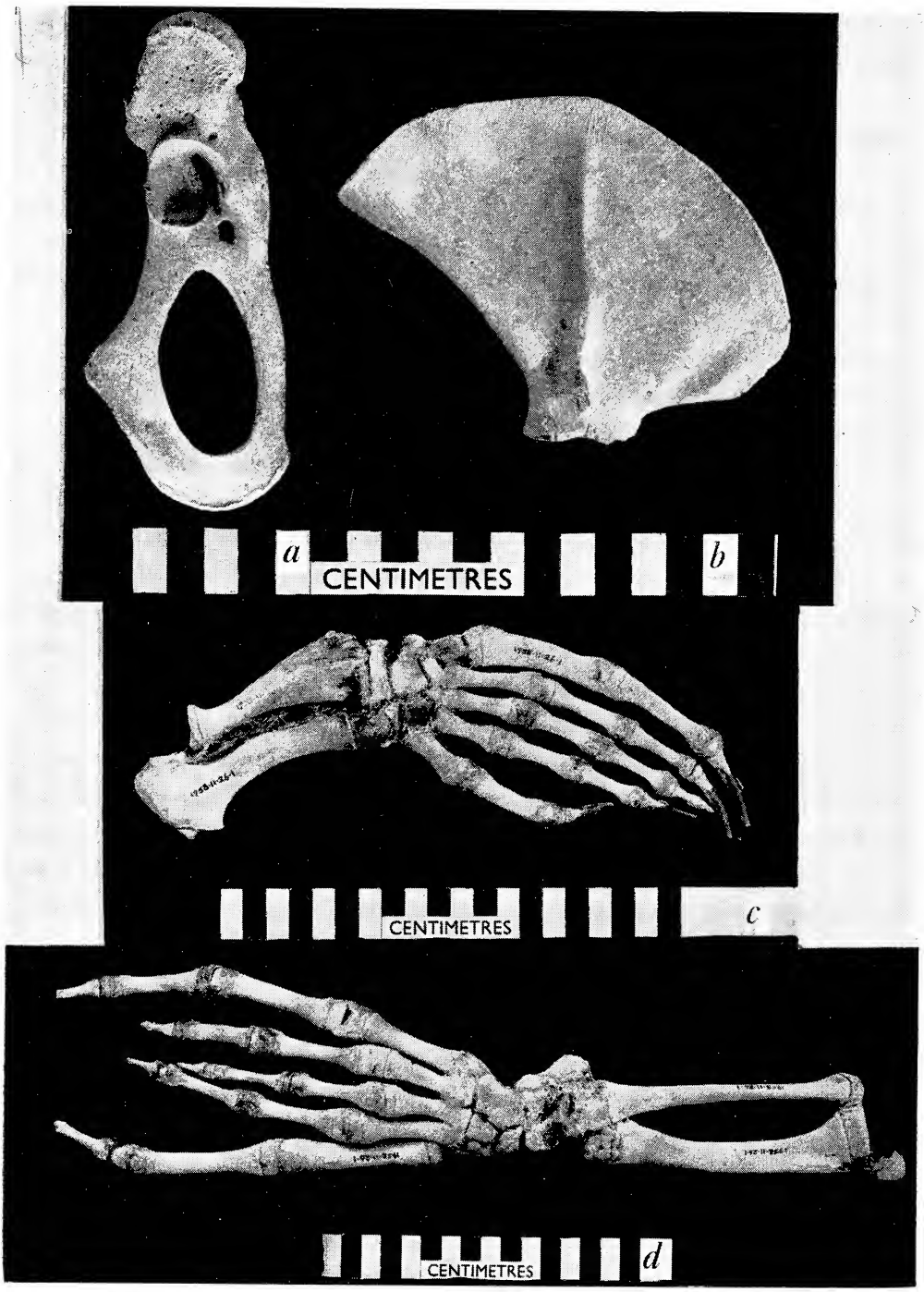

FIG. 4. *a*, Right ilium. *b*, Right scapula. *c*, Right manus. *d*, Right pes.

to the cotyloid notch that is not present in *M. monachus* or *M. tropicalis* (Fig. 4*a*).

FEMUR, TIBIA, FIBULA: These bones are not sufficiently well formed to be used for any comparison.

PES: The previous description of the pes of *M. monachus* applies also to the pes of the present animal. There is practically no indication of the insertion of the small claws on the terminal phalanges (Fig. 4*d*).

VERTEBRAL COLUMN: Vertebral formula: cervical 7, thoracic 15, lumbar 5, sacral 3, caudal 13.

Cervical vertebrae. These are more like *M. tropicalis* than *M. monachus* in that the transverse processes of vertebrae 4–6 are divided into two branches, though the division is less pronounced than in the adult *M. tropicalis.* There is a general similarity to *M. monachus,* though this is probably more because of the similarity in age. The neural arches have completely fused.

Thoracic vertebrae. These are similar to those of the young *M. monachus* except that the neural arches are narrower and do not lean so far posteriorly.

Lumbar and caudal vertebrae. These are as previously described (King, 1956).

RIBS: The articulation of the ribs is similar to that in the other monk seals. In order to inject the vascular system and remove the soft parts the cartilaginous parts of the ribs were cut away.

ABDOMINAL VEINS

The abdominal veins are thin and easily distensible. The posterior vena cava is duplicated as in *Phoca* but displays a complicated arrangement of large anastomotic channels (Fig. 5) not hitherto described in other Pinnipedia. The right limb of the posterior vena cava is the larger, is almost straight, and lies a little to the right of the midline. The smaller left limb extends from the pelvis on the left, passing somewhat obliquely cranialwards to the right to join the right limb near the upper pole of the left kidney. A large anastomotic channel passes from the right limb at the level of the lower pole of the right kidney obliquely across the midline to join the left limb at the level of the middle of the left kidney. A smaller channel arises from the right cranial end of the anastomosis just described, passes dorsal to the right limb, and enters it on the right at the level of the upper pole of the right kidney. Each limb and the two anastomotic channels receive numerous tributaries draining the renal stellate plexus as well as many vessels from the lumbar and pelvic venous plexuses. The right limb of the posterior vena cava is 2.5 cm. in diameter where it is formed by union of the iliac, lumbar, and most caudal renal tributaries. It is 3.0 cm. in diameter where it is joined by the left limb. The common trunk is 3.0 cm. in diameter throughout the 8.0 cm. of its extent to the point where it is enclosed by hepatic tissue.

The common trunk of the posterior vena cava is enlarged considerably where it enters the substance of one lobe of the multilobed liver. It has the form of a dilated tube, 15 cm. in length and 6 cm. in diameter in its cranial portion, lying on the ventral surface of the liver and surrounded on three sides by a narrow strip of hepatic tissue. Several large orifices of hepatic veins are present on the lateral walls of this dilated part of the posterior vena cava. Cranially this part of the posterior vena cava enters a hepatic sinus, nearly spherical in shape and approximately 10 cm. in diameter. The sinus is partially surrounded by hepatic tissue, but in regions only a thin translucent wall covered by peritoneum separates it from the diaphragm. The sinus is divided by two narrow septa arising from its right wall. Six large hepatic veins open into the sinus. The capacity of the sinus is estimated to be 450 cc. Figure 6 shows the appearances of the dilated vena cava and the hepatic sinus.

The intrathoracic part of the posterior vena cava is 5 cm. in length and 3.5 cm. in diameter. No pericardial plexuses of vessels, such as are found in *Phoca,* were present and no veins drained into this part of the vena cava. An incomplete sphincter of striated muscle encircles the vena cava just cranial to the diaphragm. The dorsal part of the sphincter was 3.5 cm. high and was closely adherent to the vena cava; it was separated from the diaphragmatic muscle by a narrow strip of connective tissue. The fibres of the sphincter only partially encircle the vena cava so that on its ventral aspect the sphincter is narrowed to a bundle of closely packed fibres

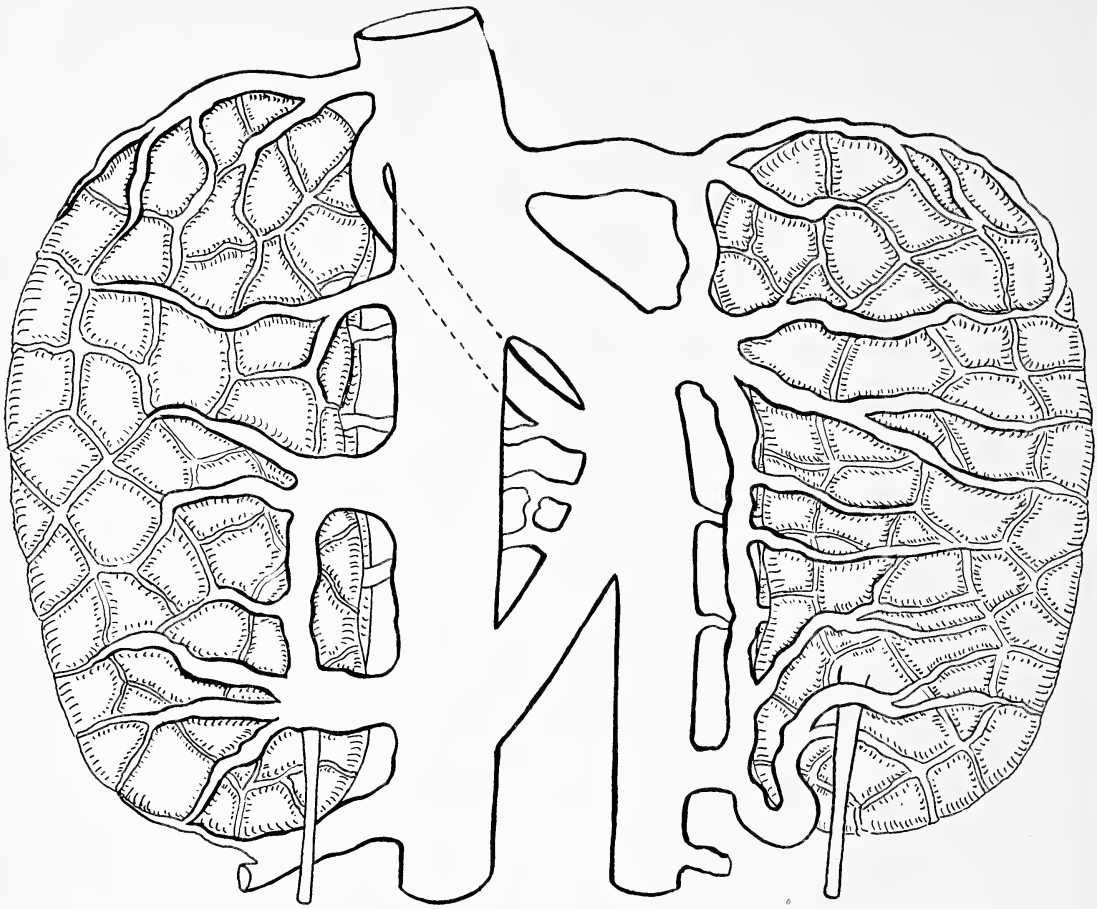

FIG. 5. A drawing from the ventral aspect to show the duplicated posterior vena cava, its anastomotic branches, and the stellate renal plexus on the surface of the multilobular kidney.

0.5 cm. high. The sphincter is shaped like a signet ring. It is supplied by branches of the right phrenic nerve.

KIDNEYS

The right kidney lies 2 cm. more cranial than the left. The right is 18 cm. long, 8 cm. broad, and 3.5 cm. thick; the left is 16 cm. long, 7 cm. broad, and 3.5 cm. thick. Each kidney is composed of large numbers of renules, each about 2.0 cm. in diameter. The papilla of each renule projects into a single calyx with a ductule that unites with others to drain eventually into the pelvis of the ureter as in *Phoca* (Harrison and Tomlinson, 1956).

Each kidney is surrounded by a stellate venous plexus, the communicating vessels of which lie in the sulci between the renules on the surface of the kidney. The plexus is more marked on the ventral aspect of the organ. There are numerous anastomoses with lumbar and lateral wall veins, with the intravertebral vein, and with the azygos vein. The plexus is drained mainly by a series of tortuous tributaries that extend round the upper and lower poles and transversely across the ventral and dorsal surfaces of the body of the kidney. These tributaries unite at the medial border of each kidney to form three or four short trunks that enter the two main limbs of the posterior vena cava or its large anastomotic

channels (Fig. 5). The major portion of venous blood is conveyed by interlobular veins reaching the surface between renules to enter the stellate plexus. Some interlobular veins, however, pass towards the hilum of the kidney to drain into small channels that extend medially to the limbs of the posterior vena cava.

HEART AND GREAT VESSELS

The aorta is markedly constricted at a point immediately to the left of the origin of the left subclavian artery and below the ductus arteriosus. This condition is known as coarctation (*coarctus* = pressed together) and is the result of partial obliteration of the dorsal aorta either between the 4th and 6th arch (above the ductus arteriosus) or below the 6th arch and the dorsal aorta (below the ductus arteriosus). It occurs rarely in man: Wood (1956) found coarctation of the aorta in 9 out of 900 cases of congenital heart disease. It appears to be very rare indeed in mammals and has not been reported in any animals dying at the Zoological Gardens, Regent's Park, London (R. W. Fiennes, personal communication). Cordy and Ribelin (1950) describe its occurrence in a bullock associated with dextraposition of the heart. It occurs, in man, more frequently in males (4.5:1), is most often found in young adults and 1 per cent of the cases have hereditary links (Wood, 1956).

FIG. 6. A drawing from the right side of a sagittal section through the dilated intrahepatic part of the posterior vena cava, the hepatic sinus, and the sphincter about the intrathoracic part of the vena cava. The hepatic sinus is divided by thin, falciform septa; the main openings of the hepatic veins are shown as black circular areas.

The transverse diameter of the monk seal aorta at the point of coarctation is 1.0 cm., that of the first part of the descending aorta is 1.4 cm. There does not appear, therefore, to be any post-stenotic dilatation of the aorta as is often found in man. The ascending aorta and its arch are dilated with marked thickening of the wall. The most dilated part is 4.5 cm. in diameter; the thickened wall is 3.0 mm. thick as opposed to the wall of the descending aorta, which is 1.0 mm. thick. At the point of coarctation the wall of the aorta is thickened by fibrous tissue to 4.0 mm. cranially and to 3.0 mm. caudally; the other parts of the aortic wall are less thick. Three aortic valves are present (only two are present in 23 per cent of human subjects with coarctation, Hamilton and Abbott, 1928). The aortic ring appears of normal size (aortic stenosis is present in 7.5 per cent of cases in man).

The left ventricular musculature appears hypertrophied, but otherwise the heart is normal. There is no patent foramen ovale and the ductus arteriosus is closed (7 per cent of human cases show a patent ductus). The right and left atria appear to be of normal size and have walls that do not look hypertrophied. There is no evidence of enlargement of vessels that provide collateral circulations above and below the constriction (internal mammary arteries). No notching of the posterior margins of the ribs (which can be caused by raised blood pressure in the intercostal vessels) is present. The lack of any such findings could well be due to the immaturity of the animal.

OTHER VEINS

A large azygos vein is present just to the right of the midline; it is 1.25 cm. in diameter and terminates in the anterior vena cava. No left-sided azygos vein is present.

An extradural intravertebral vein is present; at the level of the 12th thoracic vertebra it lies to the left of the cauda equina. At this level it measures 1.75 cm. by 1.25 cm. It is somewhat larger at the level of the 3rd thoracic vertebra. The poor preservation of the specimen prevented detailed examination of the connexions of the vein. It definitely has connexions with the azygos vein and with the lumbar veins related to the stellate renal veins at the lower poles of the kidneys as in *Phoca.* These are clearly shown after the venous system had been injected with coloured gelatin.

LUNGS

Superficial examination (no casts were made) suggests that the arrangement of the bronchial tree is symmetrical as has been described in other seals (Brown, 1958). Histological examination reveals the presence of numerous features described by Pizey (1954) in the lung of *Phoca.* The cartilages of the tertiary bronchi are continued far to the periphery of the lung, and bronchial mucous glands are frequent. The lung is divided into numerous lobules by well-marked septa of loose connective tissue. The bronchioles possess a series of myo-elastic valves which are similar to those of *Phoca* but not as marked as those in *Tursiops* (Wislocki, 1929).

TESTIS

Each testis weighs 1.9 g. and measures 25 × 15 × 10 mm. in its greatest diameters. The seminiferous tubules are inactive, immature, devoid of lumina, and average 50/μ in cross-sectioned diameter. The interstitial tissue is relatively abundant. Some of its cells are large, polyhedral, and heavily vacuolated, but the majority are small, fusiform, and have densely stained nuclei. The connective tissue between the seminiferous tubules is loosely arranged and oedematous. These appearances suggest that the gonad may well have been precociously enlarged at birth with hypertrophy of the interstitial tissue as has been described in *Halichoerus, Phoca,* and *Mirounga* (see Harrison, 1960, for references).

DISCUSSION

It is difficult to come to any definite conclusions from the examination of this skeleton of *Monachus schauinslandi,* not only because of the lack of comparative material but also because of the extreme youth of the animal. It is obvious that it is more closely related to *M. tropicalis* than to *M. monachus* but this is to be expected because of its geographical position. Kenyon and Rice (1959) suggest that further study may indicate a closer relationship between the Laysan and the West Indian monk seals and that *M. schauinslandi* may possibly be a race of *M. tropicalis.*

The Laysan monk seal possesses certain vascular (venous) modifications seen in other Pinnipedia. These are a duplicated posterior vena cava, a stellate renal plexus, a caval sphincter, a hepatic sinus, and an extradural intravertebral vein (Harrison and Tomlinson, 1956). There are, however, certain differences. The pattern of duplication of the posterior vena cava is more complicated than in any seal so far described. There is evidence of persistence of several anastomotic channels between the two limbs of the posterior vena cava. This could be interpreted as persistence of an embryonic state in which primitive anastomoses have become enlarged rather than suppressed. The hepatic sinus is not as large as in *Phoca* or *Mirounga,* whereas the curious dilatation of the intrahepatic part of the vena cava is undescribed in seals. The sphincter is not as large or as complete as in other Pinnipedia. It could be argued that the monk seal shows less vascular (venous) specialization than *Phoca, Mirounga, Leptonychotes, Lobodon, Halichoerus,* and *Hydrurga,* but more than *Zalophus.* This could mean that monk seals are not able to dive for so long a period or as deep as these forms. No observations have been made on the diving abilities of the Laysan monk seal, but Kenyon and Rice (1959) note that these seals occur regularly only on islands having extensive areas of shallow shoal water and that they appear to feed primarily on bottom-living fishes that they could obtain only in shallow water. They do travel over deep water, though not necessarily at any great depth. It must, however, be emphasized that the specimen described here had coarctation of the aorta. We are not

certain that its venous pattern is that prevailing in all Laysan monk seals, and it is frustrating that the first whole specimen available for examination should be congenitally abnormal.

It is hoped that continuing interest in this rare and relatively unknown seal will, in due course, result in the acquisition of more specimens for study. In the meantime it has been a great pleasure to see and work on the present animal and we are much indebted to Mr. Vernon E. Brock and his fellow workers for their kindness. We are also grateful to Dr. J. D. W. Tomlinson for injecting the specimen and for making some initial observations.

SUMMARY

A young male monk seal *Monachus schauinslandi* of an estimated age of 5 weeks has been received by the British Museum (Natural History). A brief description is given of the external features, stomach contents, and parasites. The skull and skeleton are described and a general similarity to that of *M. tropicalis* is noted. Certain modifications in the venous system are described; coarctation of the aorta is present.

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Hermaphroditic Skipjack[1]

RICHARD N. UCHIDA[2]

TWO PAIRS of skipjack (*Katsuwonus pelamis*) gonads, each having male and female components, have come to my attention in the past 3 years. The first was received from Mr. Thomas S. Higa, proprietor of a Honolulu fish retail market, in April 1957. Mr. Higa recovered the gonads from a neighboring fish retailer who had discovered them in a freshly eviscerated 16-lb. skipjack. This fish was captured by the "Orion," a commercial skipjack vessel, on April 11, 1957, off Makua, Oahu, from a school of 15- to 18-lb. skipjack.

The ovo-testes (Fig. 1) were typically paired and elongate, joined posteriorly, and weighed 121 gm. (fresh weight). The male and female components were easily discernible. The left gonad was divided into three segments; the anterior one-sixth and posterior one-third were ovarian and the remainder testicular. The right gonad was divided into two segments; about two-thirds of the anterior portion was testicular and the remainder ovarian. Figure 2 shows the length of each of these segments.

The cream-colored testicular sections were solid and somewhat flattened in cross-section, and did not seem to be atypical in any way. There was no running milt present, but their size suggested that they were in a rather advanced stage of maturity. All ovarian sections were pinkish, but differed in firmness. The posterior segments were hollow and flabby, with a ribbed internal cavity extending their entire length. The single anterior ovarian section was nearly round in cross-section and rather turgid.

Detailed examination of the ovo-testes was made after they had been preserved in 10 per cent formalin. The longitudinal duct of each testicular section could be followed posteriorly to the juncture of the testicular and ovarian segments, after which the ductus deferens became obscured in the network of blood vessels on the surface of the ovarian section. No openings of the ductus deferens were detected anywhere in the area of the urogenital sinus.

The two posterior ovarian sections were joined posteriorly by a single oviduct which opened into the urogenital orifice. No duct could be found in the single anterior ovarian segment.

Microscopic examination of the ova was made to determine their degree of maturity. The lumen of the anterior ovarian section was filled

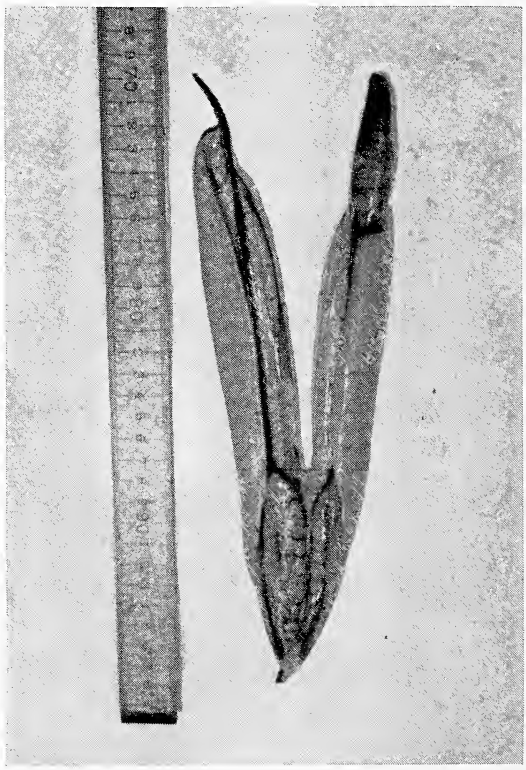

FIG. 1. The ovo-testes of a hermaphroditic skipjack (ventral view).

[1] Published with permission of the Director, U. S. Bureau of Commercial Fisheries. Manuscript received July 29, 1960.

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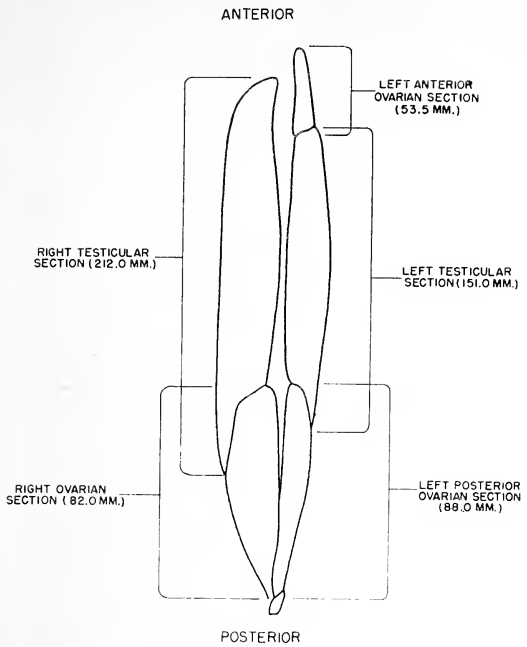

FIG. 2. Outline of the ovo-testes, showing the location and size of the male and female components (ventral view).

with a compact mass of resorbing ova, while the peripheral portion contained ova ranging from small, transparent stages to larger, opaque ova. The average diameter of 25 randomly selected larger, opaque ova was 0.504 mm. The posterior ovarian sections contained similar small and large ova, but no resorbing ova were present. Average diameters of randomly selected ova from these parts were 0.543 mm. for the left posterior member and 0.514 mm. for the right.

The presence of residual ova in the anterior section suggests that the fish had been a functional female. Assuming that the ova in each of the ovarian sections ripened at the same time, it is possible that ova were extruded from the posterior sections at spawning time, whereas ova in the anterior section could not be extruded because of the lack of an adequate duct. This could account for the presence of the resorbing ova in the lumen of the anterior ovarian section. Since the testicular sections were well developed and constituted a large part of the gonads, the fish may also have been a functional male.

The discovery of the second pair of ovo-testes was reported to the Honolulu Biological Laboratory on March 10, 1960, by Mr. Richard Nakashima of Honolulu, who found them in a 10-lb. skipjack.

The gonads, outlined in Figure 3 and labeled *A* and *B* for purpose of identification, were not joined posteriorly as a result of mutilation to both posterior ends during removal, and, therefore, could not be identified as to position (left or right). Both gonads were distinctly separated into three parts; an anterior ovarian section, a middle testicular portion, and a torn, fragmentary ovarian segment posteriorly. The testicular segments were similar to those found in the ovo-testes previously described, and contained no running milt. The ovarian sections were predominantly yellow with a tinge of pink. The anterior segments were flabby and hollow.

A starch suspension colored with powdered carmine was injected into the posterior ovarian section of gonad *A* and the flow of injected material indicated the presence of a duct connecting the two ovarian parts. A similar injection was attempted with gonad *B*, but failed

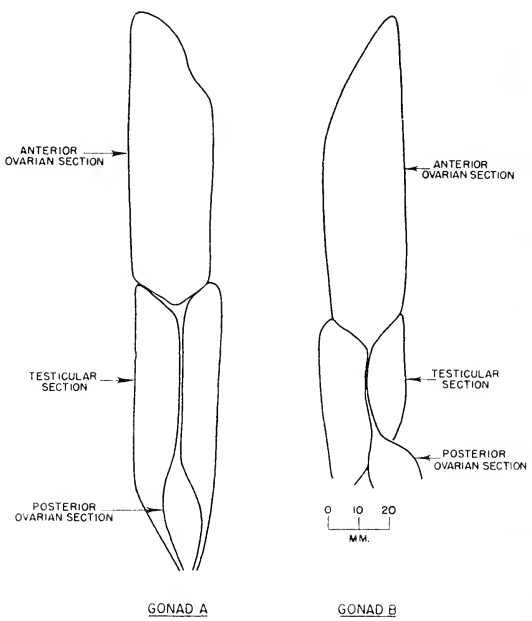

FIG. 3. Outline of the ovo-testes, showing the location and relative size of the male and female components.

to reveal any ducts owing to excessive tissue damage.

Ova diameter measurements revealed that the posterior ovarian section of gonad *A* and both ovarian segments of gonad *B* were identical in their degree of development. The ova ranged from small, primitive ova to larger, opaque ova. Average diameters of 25 randomly selected ova of the most advanced group were 0.479 mm. for the posterior ovarian section of gonad *A* and 0.476 mm. and 0.479 mm. for the anterior and posterior ovarian sections, respectively, of gonad *B*.

The development of the anterior ovarian section of gonad *A* was dissimilar to any of the sections previously examined. Its lumen contained a loose mass of large, ripe, resorbing ova, together with a few completely degenerated ova. The peripheral portion of the section contained only primitive ova. Those intermediate to the primitive and the large, resorbing ova were absent.

The presence of residual ova indicates that this fish also had been a functional female. Again, it is not clear whether the ova remnants were the unexpelled portions of a previous successful spawning or a group of ripe ova that were not expelled owing to the inadequacy of the duct. Damage to the posterior portions of both gonads made it impossible to determine whether the male ducts were connected to the exterior, but since the testicular segments were well developed, this fish may also have been a functional male.

Hermaphroditism in skipjack is an extremely rare occurrence. So far as is known, only one other example has been recorded and described (Nakamura, H., 1935, Trans. Nat. Hist. Soc. Formosa 25(141): 197–198; in Japanese).

Studies on Pacific Ferns, Part IV
The Pteridophyte Flora of Pitcairn Island

G. Brownlie[1]

Although the ferns of southeastern Polynesia have been described in several papers, no separate list has previously been provided for Pitcairn Island. The present paper outlines the details of a collection made there by Mr. W. H. Lintott of the Botany Department of the University of Canterbury, and includes mention of other collections where these were available. When the changes which have occurred in the indigenous vegetation are considered, it is remarkable that, as well as finding all the other species noted earlier, one species not previously recorded from Pitcairn is included in the most recent collection.

Of the 20 species listed, 15 are widespread throughout Polynesia, and 2 others are probably local derivatives of similarly widespread species. This large group represents the dominant Malay-Papuan element found in decreasing numbers of species from west to east in the tropical Pacific. Of the remaining 3, 1 species of *Asplenium* and 1 of *Trichomanes* are found in S.E. Polynesia and New Zealand, and are the only ones to which Copeland's (1938) ideas of an Austral group can be applied. The single species of *Cyathea* is related to ferns found in Rapa and the Society Islands. There are only 2 species recognised as endemics, and each of these may in fact be better regarded as varieties. Viewed as a whole, the pteridophyte flora of this region, Pitcairn, Rapa, and the Australs, appears to be merely an extension of that of the Society Islands.

Abbreviations: C, Department of Botany, University of Canterbury; W, Dominion Museum, Wellington; S, Department of Agriculture, Suva, Fiji; K, The Herbarium, Royal Botanic Gardens, Kew.

[1] Department of Botany, University of Canterbury, Christchurch, New Zealand. Manuscript received April 25, 1960.

PSILOTACEAE

Psilotum nudum (L.) Grisebach

Pendant on trees and shady rocks; not common. Widely distributed throughout Polynesia.

Lintott 167a and 167b (C), Williams 3068 (W), Twyford S.P. 129 (S).

MARATTIACEAE

Angiopteris chauliodonta Copeland

On damp hillsides in dense shade. I doubtfully retain this as a distinct species, and it may be only a local form in which the sterile apices of the pinnules are more toothed than is usual in *A. evecta.*

Lintott 150 (C), Twyford S.P. 130 (S).

GLEICHENIACEAE

Dicranopteris linearis (Burm.) Und.

Gleichenia linearis (Burm.) Clark. Brown, B.P. Bishop Mus. Bull. 89, 97, 1931.

Copeland, Occ. Pap. B.P. Bishop Mus. 14(5): 52, 1938.

Forming tangled masses on dry hillsides. Widely distributed in the tropics and subtropics of the Old World with many recognized varieties in S.E. Asia. It is probable that there are also several varieties in the Pacific area, but these have not been worked out.

Lintott 163, 164 (C), Twyford S.P. 135 (S), Williams 3038, 3081 (W), Fosberg 11221 (K), Quayle No. X (K).

HYMENOPHYLLACEAE

Trichomanes endlicherianum Pr.

Damp rocky faces in shady stream bed. This is the only record of a member of this family from Pitcairn, and as it appears to be fairly uncommon, it has presumably been overlooked by previous collectors. The specimens are some-

what smaller than those from the Austral Islands and New Zealand, but they have the characteristic single row of elongated marginal cells. The species is found in New Zealand, the Kermadecs, Samoa, Fiji, Tahiti, the Australs, and Rapa.

Lintott 155 (C).

PTERIDACEAE

Adiantum hispidulum Sw.

In isolated clumps on dry slopes and in rocky crevices. All examples are considerably smaller than those seen from the larger Pacific islands. The species is widely distributed in the tropics and subtropics from Africa to Polynesia and south to New Zealand.

Lintott 152, 152b (C), Twyford S.P. 51 (S), St. John 15031 (K).

CYATHEACEAE

Cyathea cumingii Bak.

Tree fern up to 10 ft. high, occurring in several places on the island. Elsewhere known only from the Australs, but *C. rapensis* and *C. societarum* are very similar, if not identical.

Lintott 165 (C), Williams 3010, 3011 (W), Twyford S.P. 132 (S), Quayle No. 1 (K), Cuming 1393 (K), Matthews No. 7 (K), Fosberg 11241 (K), St. John 14978 (K).

DAVALLIACEAE

Davallia solida (Forst.) Sw.

Common everywhere, creeping on the ground and as an epiphyte on old trees. Four local forms have been recognized in S.E. Polynesia by Brown (1931), but the species is everywhere somewhat variable in degree of division of the fronds and in shape of the indusia. It is distributed from Burma to Pitcairn.

Lintott 162 (C), Williams 3013, 3052 (W), Twyford S.P. 133, 134 (S), Quayle No. X (K), St. John 15048 (K).

Nephrolepis biserrata (Sw.) Schott

Common throughout the island underneath *Pandanus*. Christensen (1943) regards the Polynesian-Asiatic forms as probably distinct from genuine African *N. biserrata,* but until a complete revision of the genus has been carried out it is preferable to retain the well-known name. The distribution of the species in its widest sense is pantropic.

Lintott 158 (C), Williams 3074, 3079 (W), Twyford S.P. 59(S), Quayle No. 1 (K).

Nephrolepis hirsutula (Forst.) Pr.

Fairly common, particularly around clearings. Very variable in all its characters, often approaching close to *N. biserrata,* although it is usually smaller than that species. Distributed from tropical Asia to Pitcairn.

Lintott 169 (C), Williams 3051, 3078 (W), Twyford S.P. 136 (S).

ASPIDIACEAE

Thelypteris uliginosa (Kze.) Ching

Dryopteris setigera (Bl.) Kze. Brown, B.P. Bishop Mus. Bull. 89, 30, 1931.

On cleared banks along shady tracks. I have seen no fertile specimens of this fern from Pitcairn, and it appears to be relatively uncommon. The species is widespread in the tropics and subtropics from Asia through the Pacific to Pitcairn.

Lintott 168 (C), Twyford S.P. 131 (S).

Rumohra aristata (Forst.) Ching

Polystichum aristatum (Forst.) Pr. Brown, B.P. Bishop Mus. Bull. 89, 38, 1931.

Copeland, Occ. Pap. B.P. Bishop Mus. 14(5): 57, 1938.

Forming small patches under trees on hillside ridge of Adamstown. Brown was in error in comparing specimens of this fern from Rapa with New Zealand forms, for, although found in the Kermadecs, it does not occur on the mainland of New Zealand. Distribution is throughout the tropics and subtropics of the Old World.

Lintott 154 (C), Quayle No. X (K), St. John 14969 (K).

Cyclosorus parasiticus (L.) Farwell

Dryopteris parasitica (L.) Kze. Brown, B.P. Bishop Mus. Bull. 89, 22, 1931.

Dryopteris dentata (Forst.) C. Chr. Copeland, Occ. Pap. B.P. Bishop Mus. 14(5): 56, 1938.

Common everywhere in shady positions. The habit of these specimens is almost intermediate between typical *C. parasiticus* and *C. nymphalis,* but since the leaves are not fascicled it is better to place it in the former species. I feel that Brown's recognition of a local variety based chiefly on characters of size is, however, unsound. Widely distributed from tropical Asia through the Pacific.

Lintott 156 (C), Williams 3049, 3076 (W), Twyford S.P. 100 (S).

Athyrium polyanthes (Sol. ex Bak.) Copel.

Diplazium polyanthos (Sol.) C. Chr. Brown, B.P. Bishop Mus. Bull, 89, 55, 1931.

Athyrium pitcairnense Copel., Occ. Pap. B.P. Bishop Mus. 14(5): 60, 1938.

Diplazium harpeodes Moore. C. Chr., B.P. Bishop Mus. Bull. 177, 76, 1943.

Not common; found in isolated clumps in shady valleys. Much of the confusion concerning the nomenclature of this species was cleared up by Christensen (1943), but I prefer to follow Copeland in uniting *Diplazium* and *Athyrium.* Copeland's local species falls within the range of the species as outlined by Christensen. Distribution is throughout the Pacific islands from Fiji to Pitcairn.

Lintott 166 (C), Cuming 1389 (K), Matthews unnumbered (K).

BLECHNACEAE

Doodia media R. Br.

Fairly common on open ground and underneath *Pandanus.* Distributed from Australia and New Zealand to Pitcairn, but absent from Samoa and Tahiti.

Lintott 159a and 159b (C), Williams 3044 (W), Twyford S.P. 133, 134 (S), St. John 14976 (K).

ASPLENIACEAE

Asplenium nidus L.

Common in one or two valleys and cultivated in local gardens. Widely spread throughout the tropics of the Old World.

Lintott 153 (C).

Asplenium obtusatum Forst.

On rocks on the south coast, and in small caves. Always within or close to the spray zone. The specimens are similar to those found on Rapa, the Australs, and other Pacific islands, but are somewhat smaller than the typical state represented in New Zealand. Elsewhere the species is found in Juan Fernandez and southern Chile, with closely related, if not identical, species on Tristan da Cunha and Tasmania.

Lintott 170 (C), Williams 3083 (W), Twyford S.P. 71, 73 (S), Fosberg 11343 (K).

Loxoscaphe gibberosum (Forst.) Moore

Loxoscaphe gibberosum var. *pitcairnense* Brown, B.P. Bishop Mus. Bull. 89, 67, 1931.

Common everywhere in deep shade. This species shows so much variation in the degree to which the leaf segments extend beyond the sorus that I feel that Brown's varieties are difficult to maintain. It is found in the Pacific region from Fiji to Pitcairn, but is absent from Samoa.

Lintott 157 (C), Williams 3012, 3053 (W), Twyford S.P. 43 (S), Matthews unnumbered (K), Cuming 1373 (K), Fosberg 11297 (K).

POLYPODIACEAE

Pyrrosia angustata (Sw.) Ching

Cyclophorus angustatus (Sw.) Desv. Brown, B. P. Bishop Mus. Bull. 89, 93, 1931.

Common on rocks in inland situations, and as an epiphyte on large trees. The species is

widely distributed in tropical areas from Malaya to Polynesia.

Lintott 161a, 161b (C), Williams 2997, 3075, 3082 (W), Twyford S.P. 153 (S), Matthews unnumbered (K), Cuming 1394 (K).

Phymatodes pitcairnense (Copel.) Brownlie, comb. nov.

Polypodium phymatodes L. Brown, B.P. Bishop Mus. Bull. 89, 87, 1931 (in part).

Microsorium pitcairnense Copel. Occ. Pap. B.P. Bishop Mus. 14(5): 74, 1938.

Common, creeping on banks along paths. This is a close relative of *P. nigrescens,* but without the distinct veins of that species. Unlike Copeland, I do not find that the sori of any of the specimens are relatively marginal, so that these may not be the same as his species. However, until a full revision of the Pacific members of this genus is undertaken, I feel that it is unwise to introduce further new names for minor differences.

Lintott 160 (C), Williams 3067, 3077, 3084 (W), Twyford S.P. 36, 65 (S), Matthews No. 12 (K).

VITTARIACEAE

Vittaria elongata Sw.

Local, in one area growing on moist rocks. The limitations of this species are somewhat uncertain in the Pacific area, and the Pitcairn example is doubtfully assigned to it. It may in fact be closer to *V. rigida* var. *samoensis* described by Christensen (1943). In the widest sense the species extends from tropical Asia to Polynesia.

Lintott 151 (C), Fosberg 11309 (K).

In addition to the above-listed species there are two sheets at Kew (Cuming 1388) identified as *Polypodium sandwicense.* The specimens belong to the genus *Ctenitis* and approach close to *Dryopteris samoensis* (C. Chr. 1943), but the fact that it has not been found by any subsequent collector indicates that it is probably extinct on Pitcairn or has been wrongly accredited to that island.

I wish to thank the professors W. R. Philipson and Harold St. John for making the Lintott collection available for study, and I wish to acknowledge the use of material from the Dominion Museum, Wellington, the Department of Agriculture, Suva, and the Herbarium, Royal Botanic Gardens, Kew.

The Principal Weedy Melastomaceae in Hawaii

D. L. Plucknett and B. C. Stone[1]

None of the numerous species of Melastomaceae is native to the Hawaiian Islands, yet at present at least a dozen species in nine different genera are found as weeds or seminaturalized plants in various localities in the Islands. Some of these species are hardly known out of cultivation, others are frequent in certain small areas, while a few are well-known common plants on most of the islands in the chain. Certain areas have become thickly populated with one or another of these species, and waste and pasture areas have been invaded, becoming in some cases nearly impenetrable thickets. Two or three of these species must be regarded as noxious weeds.

In Hillebrand's *Flora of the Hawaiian Islands* (1888) there is no mention of any melastomaceous species. Degener (1935: family 274) mentions *Heterocentron,* and (1930: 226) mentions *Tibouchina semidecandra* and *Melastoma malabathricum.* Earlier, W. T. Pope (1929: 147) had mentioned *Melastoma decemfidum* and stated that it had escaped from cultivation on Kauai, and had been introduced (presumably from a Florida nursery) in 1916. It seems from recent collections that this plant mentioned by Pope is, as Degener indicated, *M. malabathricum;* although both species are present in the Islands, only this one has been found on Kauai. The *Tibouchina* is said to have been introduced to Hawaii in 1910.

Degener indicated the pestiferous nature of these plants, and his prediction that they would spread has come true. At present they have a very spotty distribution, but where they have spread they often form virtually pure stands which have blighted many areas of natural vegetation and have become a foe of both the agriculturist and conservationist. Hosaka (1945) referred to *Melastoma malabathricum* as "an aggressive shrub that forms dense stands—crowds out other plants . . . has no forage value."

Recently the extent of bauxitic or aluminous soils in Hawaii has been publicized (Sherman, 1954), and plants which accumulate aluminum have been the subject of a paper by Moomaw, Nakamura, and Sherman (1959). Among the Hawaiian plants found to accumulate aluminum was *M. malabathricum,* a known accumulator of aluminum in other areas (Webb, 1954). None of the other melastomaceous plants in Hawaii was used in the study by Moomaw *et al.,* but other species of the Melastomaceae are reported by Webb to accumulate aluminum.

The purpose of this paper is to discuss the distribution and spread of the noxious Melastomaceae in Hawaii with special reference to the most common species and to provide a key and brief descriptions of each as a preliminary step for a possible study of bauxitic soils and aluminum-accumulating species of Melastomaceae.

Three species are found on more than one island and may be considered common. These are *Tibouchina semidecandra, Melastoma decemfidum,* and *M. malabathricum.*

Three other species are rather abundant in a few isolated locations on one or two islands. These are *Clidemia hirta, Pterolepis glomerata,* and *Heterocentron subtriplinervium.*

The remaining species are restricted to a few small areas and do not threaten to become noxious weeds. These are *Oxyspora paniculata, Arthrostemma latifolium, Tetrazygia bicolor,* and *Medinilla magnifica.* Some of these species are referred to by Neal (1948: 569).

KEY TO COMMON SPECIES

Petals and all anthers brilliant purple; leaves densely silvery-pubescent with soft hairs, especially on undersides; open shrubs up to 12–15 ft. tall....*Tibouchina semidecandra* (1)

Petals pink, stamens pink or yellow; leaves

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pubescent but not densely silvery; with stiff hairs; compact shrubs usually 10 ft. tall or less.

1. Petioles and nodes set with sparse long stiff hairs up to 5 mm. long; calyces rather sparsely scaly; ribs below sparsely scaly; lateral veins more or less glabrous..... *Melastoma decemfidum* (2)
2. Petioles and stems set with numerous short spinules to 1 mm. long; nodes with a few long scales; calyces silky with numerous scales; ribs and small veinlets rather densely scaly-spiny below ..... *Melastoma malabathricum* (3)

1. *Tibouchina semidecandra* (Schrank and Mart.) Cogniaux

DISTRIBUTION: *Kauai:* Kokee, open grass area by museum, on ditch bank by roadside, Dec. 23, 1959, D. L. Plucknett 81–85.

Hawaii: N.W. Kilauea Crater, wet fern forest around houses, 1150 m., Aug. 30, 1933, Fosberg 10121. Volcano Road, near volcano, forest reserve along road, in mixed fern forest, tall shrub 5 m. high, Nov. 10, 1926, L. H. Mac Daniels 223. Volcano House, July 24, 1926, Aug. 24, 1926, C. S. Judd. 29 miles, Glenwood, Hawaii, July 23, 1926, Degener 8188; June 22, 1929, persistent in forested region, Degener 9641. Glenwood, el. 1000 m., in forest, Dec. 25, 1930, E. H. Bryan, Jr., 714. Kalanilehua, Aug., 1917, J. F. Rock 13029, 13030. Kurtistown, Jan. 20, 1960, along roadside, D. L. Plucknett 95. Hilo, May, 1932, A. Meebold.

Oahu: Nuuanu Valley, upper part near Upside Down Falls, well established in underbrush in thick woods, shrub 2 m. tall, flowers deep purple, Fosberg 27067, Sept. 15, 1946. Tantalus, grounds of E. F. Bishop, Oct. 3, 1930, H. E. Gregory. Observed, Manoa Valley, by Manoa stream, B. C. Stone, Feb. 1960.

Altitude range 1,500–4,500 ft.; requires moist relatively cool habitat. At lower elevations it is usually under shade, but at Kilauea Crater it may be found in the open (elev. 3,400 ft.). This species is a spectacular shrub and in cultivation is very attractive. It does not appear to be as aggressive as the two *Melastoma* spp. and tends to spread only in disturbed areas. It has not been found deeply penetrating the native forest, but is often very common along roadcuts, houselots, trails, and near buildings.

2. *Melastoma malabathricum* L.

DISTRIBUTION: *Kauai:* Kilohana Crater, dominant shrub, 320 m., 7 Aug. 1928, E. H. Bryan 626. Reservoir near Hanahanapuni Crater, Mar. 24, 1960, Plucknett 116, 117. Wailua bauxite project area, Mar. 24, 1960, Plucknett 118–123.

Hawaii: Anauulu Rd. above Hilo, side of gully in canefield, flowers pink, Dec. 7, 1933, alt. 400 m., Fosberg 10490. Kaumana, alt. 200 ft., flowers pink, Sept. 1953, Amy Suehiro. Keaau Orchard–Volcano Highway Intersection, by roadside, Dec. 4, 1959, Plucknett 78. Hilo–Volcano Road, 4 miles mauka, Jan. 20, 1960, roadside, Plucknett 93, 94. Hilo radio tower, Jan. 20, 1960, Plucknett 89, 90, 92.

Altitude range 0–1,000 ft. In contrast to *Tibouchina, Melastoma malabathricum* is tolerant of drier and warmer habitats and tends to spread in lowland areas rather than in disturbed areas of native forest. Usually found in open habitats such as pastures, waste areas, and fields with weedy vegetation. On Kilohana Crater on Kauai and the adjoining areas where it once was dominant, *Rhodomyrtus tomentosa* (Ait.) Hassk. appears now to be replacing it, but it still remains an important weedy species in this area.

Pope's reference (1929: 147) to *Melastoma decemfidum* on Kauai is probably in error since only *M. malabathricum* has been found on that island. The plant is known on Kauai as "Isenberg bush" probably because of its association with Kilohana Crater and the Isenberg home there. *Rhodomyrtus tomentosa* has also been called "Isenberg bush" on Kauai but it more commonly is known as "Indian gooseberry."

On Hawaii *Melastoma malabathricum* may be found in great abundance in the Keaukaha area near the Hilo Airport and along the Volcano Road.

M. malabathricum is vigorous in growth and spreads rapidly from numerous seeds, usually spread by birds.

3. *Melastoma decemfidum* Roxb.

DISTRIBUTION: *Hawaii:* Hilo, sent to J. Kim, Honolulu, B. Ag. Forestry, 10 Dec. 1957. Hilo–

Volcano Road, 4 miles above Hilo, top of road cut, Dec. 5, 1959, Plucknett 79, 80.

Altitude range 0–1,000 ft. Flourishes in open areas of high rainfall on Hawaii. Together with its weedy relative, *M. malabathricum, M. decemfidum* has become dominant in the Keaukaha area near the radio tower and also may be seen in thickets along the Volcano Road. This shrub has been observed as a small tree with a trunk 4–5 in. in diameter and up to 12 ft. high in the Keaukaha area.

LESS COMMON MELASTOMACEOUS PLANTS IN HAWAII

There are several species which seem to be spreading in certain areas but which at present cannot be classed as dangerous or even common weeds. It seems useful to indicate briefly their presently known distributions.

Clidemia hirta (L.) D. Don. This rather small plant has been collected on Oahu on Mt. Tantalus, twice on the Poamoho Trail in the Koolau range, and twice near the Hawaiian Sugar Planters' Association nursery in Wahiawa. There are no reports of *Clidemia* from the other islands.

Pterolepis glomerata (Rottb.) Miquel. Specimens of this plant have been collected from Palikea in the Waianae range, and from Poamoho and Pupukea in the Koolau range on Oahu.

Heterocentron subtriplinervium (Link and Otto) Br. and Bouche. According to the labeled specimens in Bishop Museum there are four species of *Heterocentron* in Hawaii, but probably only one or two of these species are actually represented. Neal (1948: 568) reported only *H. roseum* Br. and Bouche. Clarification of the species of *Heterocentron* will probably be presented in the new edition of Neal's *In Gardens of Hawaii* (in preparation).

There are five specimens determined as *H. subtriplinervium* in the Bishop Museum. These were collected from Mt. Tantalus, Oahu, and from Hawaii along the Hilo–Kona and Hilo–Kilauea roads.

Arthrostemma latifolium D. Don. This plant has been found escaping at the Makiki Nursery, in Honolulu, and along south Opaeula ridge on Oahu.

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Leaf and Air Temperature under Hawaii Conditions

T. L. NOFFSINGER[1]

AIR TEMPERATURE may give a poor indication of the actual temperature experienced by a plant leaf under various meteorological conditions. Leaf temperature is dependent upon the type and condition of the plant as well as on a number of meteorological elements including wind, humidity, cloud cover, solar radiation, and air temperature.

MATERIALS AND METHODS

During the period from March 9 through April 15, 1960, leaf and air temperatures were measured using a 12-channel single-input thermister-type thermometer. Leaf temperatures of pineapple and papaya plants were measured using a 22-gauge hypodermic probe. Air temperature was measured with the thermister air temperature probe and checked with a standard mercury-in-glass thermometer. The wet-bulb temperature was determined by a standard psychrometer and solar radiation was measured by a recording bimetallic actinograph (pyrheliometer).

Soil temperature was measured from a mercury-in-glass thermometer implanted 4 in. in the soil.

In measuring leaf temperatures the needle was carefully inserted from the underside of the leaf, parallel to the leaf veins, to approximately ½ in.; i.e., at least ½ in. of the probe was enclosed within the leaf tissue. All temperatures were read to the nearest 0.1° C. The average temperature of the plant was taken as the mean value obtained from one leaf exposed to solar radiation and one in shade.

RESULTS

Data were collected at 0800, 1200, and 1600 hr. during the period of March 9 through April 15. In addition, a continuous hourly collection was made over a 24-hr. period from 0800, April 11, through 0700, April 12.

During the daylight hours pineapple leaf temperature was consistently higher than the air temperature measured in an instrument shelter at the same elevation as the plants. The values usually ranged from 1.5° to 3.5° C. above the air temperature but occasionally a leaf exposed to direct sunlight had a temperature as much as 7.6° C. higher than the air temperature.

The corresponding average temperature of the papaya leaf was consistently lower than the air temperature. Temperature of leaves exposed to direct solar radiation and temperature of leaves on the same plant but shaded by higher leaves are given in Table 1 together with the average air temperature, average leaf temperature, soil temperature, and solar radiation values.

Table 2 gives air temperature, leaf temperature, insolation values, soil temperature, cloud cover, and wind speed at 4-hr. intervals for a 24-hr. period April 11 through April 12. Maximum air temperature (27.0° C.) occurred at 1300; maximum soil temperature for the pineapple (28.0° C.) occurred at 1400; maximum soil temperature for the papaya (30.5° C.) occurred at 1500 and 1600. Maximum average leaf

TABLE 1

LEAF AND AIR TEMPERATURE AND RELATED METEOROLOGICAL DATA FOR MARCH 9–APRIL 15, 1960

TIME	0800	1200	1600
Air temperature °C.	21.5	26.7	26.4
Leaf temperature °C.			
Pineapple			
average	23.2	29.1	26.6
in sun	24.7	31.0	28.0
in shade	21.7	27.2	25.2
Papaya			
average	21.3	25.4	24.5
in sun	21.7	25.9	24.9
in shade	20.9	24.9	24.1
Insolation Langleys/min.	0.21	0.99	0.74
Soil temperature			
Pineapple	19.5	26.4	26.3
Papaya	19.5	27.1	29.8

[1] Climatologist, Land Study Bureau, University of Hawaii. Manuscript received May 19, 1960.

TABLE 2

LEAF AND AIR TEMPERATURE AND RELATED METEOROLOGICAL DATA FOR 0800 APRIL 11–0800 APRIL 12, 1960

TIME	0800	1200	1600	2000	2400	0400	SUNRISE
Air temperature °C.	22.0	25.7	26.7	22.3	22.2	21.9	22.0
Leaf temperature °C.							
Pineapple							
average	23.5	29.5	27.1	21.7	21.5	22.1	21.7
in sun	25.0	31.5	29.0	.....	.....	.....	.....
in shade	21.9	27.5	25.1	21.7	21.5	22.1	21.7
Papaya							
average	21.3	25.1	24.8	21.2	20.5	21.0	21.7
in sun	21.6	25.0	26.0	.....	.....	.....	.....
in shade	21.0	25.1	23.5	21.2	20.5	21.0	21.7
Insolation							
Langleys/min	0.27	1.43	0.98	.....	.....	.....	.....
Soil temperature							
Pineapple	20.2	26.5	27.0	23.7	21.4	21.4	20.5
Papaya	20.5	27.0	30.5	24.2	21.2	21.2	20.5
Cloud cover (1/8 S.)	5	6	1	1	1	5	1
Wind (knots)	8	8	10	5	4	0	0

temperature in the pineapple plant (29.6° C.) occurred at 1500 and in the papaya plant (26.8° C.) at 1300.

DISCUSSION

Plants undergo irradiation from the sun, clouds, and sky during the daylight hours, and at night they radiate heat outward. Mäde (Geiger, 1950: 278–280) kept a continuous record of leaf temperature over a period of two days and found that during the middle of the day the leaf surface of *Bilbergia nutaus* (a hothouse plant of the pineapple family) was as much as 10° C. higher than the air temperature. The interior portion of the pineapple fruit exposed to the direct rays of the sun at latitude 21° N. may experience temperature from 5° to 8° C. above the free air temperature. In Formosa it has become a practice to shade the pineapple fruit in order to prevent heat damage from solar radiation (Ekern, personal communication). Waggoner and Shaw (1952) have shown that energy losses from potato and tomato plants at night due to transpiration may be very small. Geiger (1950: 276) states that plant temperature is generally higher than that of air temperature when the ground surface is warmer than the air layer resting upon it, and that by night the plant is, for the most part, cooler than the air. An examination of air, soil, and leaf temperatures in Tables 1 and 2 shows that the generalization made by Geiger holds for pineapple, but that the average leaf temperatures of the papaya were consistently lower than the air temperature even during periods of relatively high soil temperature. In one observation during the period (not shown in the table), the temperature of the papaya leaf exposed to the sun registered 2.6° C. higher than the air temperature. At that time the value for solar radiation was 1.42 calories per sq. cm. per min., the sky was five-eighths covered with cumulus and stratocumulus clouds and a light sprinkle of rain was falling from clouds immediately to the N.E. of the station.

SUMMARY

Air temperature in an instrument shelter at the level of the plants does not provide a good measure of plant temperature. Papaya, with a respiration and transpiration pattern characteristic of the mesophytes, shows a leaf temperature which remains relatively near the air temperature but may be higher or lower than the air temperature, depending upon the condition of radiation, cloud cover, and wind. Pineapple, a xerophyte, has leaf temperature during the daylight hours which average 1.5° to 3.5° C. above

the air temperature, and for short periods of high solar radiation a leaf temperature 7.6° C. above the air temperature was recorded. Generally, leaf temperatures of both pineapple and papaya were below the air temperature during the night except for one period in which clouds moved into the area. At 0400, April 12, with five-eighths cloud cover and calm wind, the temperature of the pineapple leaf rose to 0.3° C. above the air temperature.

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NOTE

The Species Commonality Index: A Method for Comparing Habitats

Ecologists have used a variety of methods for comparing habitats in order to point up their similarity and to predict the efficacy of transplants. Some methods are based upon what are believed to be outstanding physical differences and similarities between the habitats, while others are based upon faunal and floral similarities and differences. The following is a method based upon faunistic similarity.

For 3 years the writer has used a simple technique involving the number of species in common between two habitats in order to arrive at a single value for comparison. This number, the Species Commonality Index (SCI), is arrived at by dividing the number of species common to both habitats by the total number of species present, as shown in the following example.

HABITAT I	HABITAT II
Species Present	*Species Present*
A	A
B	B
C	C
L	L
M	N
O	P
R	Q
S	U
T	V
	W

Species in Common = 4

Total Number of Species = 15

$$\text{Species Commonality Index} = \frac{4}{15} = .27$$

In order to make even semivalid comparisons using this technique, the collections should be thorough and reasonably concurrent. The writer has found that a large group of interested students (for example a group of young biology majors), make very comprehensive collections. The following data were compiled by 30 students in an elementary ecology class at Western Washington College of Education during the months of March and April, 1960, and show to what purpose the SCI might be used.

From inspection of the data shown in Table 1, it is apparent that Whatcom Rapids and Bad Pond are least similar. One would expect a rapids area to bear little faunistic similarity to a pond habitat, and thus it is seen that whenever Whatcom Rapids is compared to a pond, the SCI is relatively quite low, except when compared with Mud Lake, and here is seen the third highest index. From this, it might be concluded that, ecologically, Whatcom Rapids is more similar to Mud Lake than to any other habitat shown, and thus, if no other information were available, it could be assumed that a transplant from the Rapids to Mud Lake might stand a fair chance of surviving.

Further inspection of the data shows that Lake Fragrance and Good Pond are ecologically most similar. This is surprising in view of the fact that the two habitats are separated by more than 50 mi. and lie at elevations differing by more than 1,000 ft. Good Pond and Bad Pond, however, lie less than 100 ft. apart, but, according to the SCI, they seem to be relatively quite different. The writer had assumed that the two bodies were connected until subsequent investigation spurred by the low SCI revealed complete separation. Lacking other information, the writer would stake more on a transplant being successful between Lake Fragrance and Good Pond than between Good Pond and Bad Pond —even though the latter two are adjacent. This opinion is supported somewhat by knowledge

TABLE 1

DATA COMPARING VARIOUS FRESH WATER HABITATS IN THE BELLINGHAM, WASHINGTON, AREA USING THE SPECIES COMMONALITY INDEX (SCI)

COMBINATION	TOTAL NO. SPECIES	NO. SPECIES IN COMMON	SCI
Whatcom Rapids Lake Fragrance	28	5	17
Good Pond Bad Pond	24	8	33
Bad Pond Peat Bog	18	9	50
Good Pond Peat Bog	19	6	32
Lake Fragrance Good Pond	22	12	55
Lake Fragrance Bad Pond	24	8	33
Lake Fragrance Peat Bog	23	7	30
Whatcom Rapids Mud Lake	28	11	39
Whatcom Pools Good Pond	23	8	35
Whatcom Pools Bad Pond	21	8	38
Whatcom Pools Peat Bog	21	8	38
Whatcom Rapids Good Pond	26	5	19
Whatcom Rapids Bad Pond	24	4	16
Whatcom Rapids Peat Bog	22	4	18
Fragrance Lake Mud Lake	24	10	42
Mud Lake Good Pond	24	9	37
Mud Lake Bad Pond	25	7	28
Mud Lake Peat Bog	24	7	29
Whatcom Pools Whatcom Rapids	24	9	38
Whatcom Pools Lake Fragrance	28	6	21
Whatcom Pools Mud Lake	27	6	22

common to fishermen in the locality, that trout stocking is much more successful in Good Pond than in Bad Pond—thus the names for the two ponds.

It should be emphasized that the method is useful only if:

1. *Thorough and complete collections are made.* It is obvious that the greater the number of species in common, the greater the similarity of niches, and the more similar the physical attributes to account for the species similarity. Thus, the more thorough the collection, the more valid the results.

2. *The collections are made as concurrently as possible.* This prevents seasonal variation from giving too low an index. If an index is desired which covers a longer period, then of course concurrent collections should be made over several seasons.

3. *Statements such as, "Mud Lake and Bad Pond are twice as dissimilar as are Lake Fragrance and Good Pond," are unwarranted.* It is certainly possible to have a zero SCI but for the habitats to have many similarities.

4. *The method is applied within limited areas where biotic communication between habitats is constantly possible and likely.* For example, it would be unrealistic to compare a pond in New Zealand with one in Washington by this method. Even though the physical attributes of the habitats might be very similar, there is no chance of obtaining a high index.

It is the writer's intention in the future to make more thorough collections of these same areas and of others, and to attempt relating the various indexes to the physical characteristics of the habitats.—*Charles J. Flora, Department of Biology, Western Washington College of Education, Bellingham, Washington.*

should not be fastened together in any way, and should be mailed flat. Inserts should be either typed on separate sheets or pasted on proper page, and point of insertion should be clearly indicated.

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PACIFIC SCIENCE

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Revision of the Genus Pandanus
Part 3. A New Species from the Tuamotu Archipelago
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Daylight Surface Occurrence of Myctophid Fishes

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On Zooplankton of Some Arctic Coastal Lagoons of Northwestern Alaska, with Description of a New Species of *Eurytemora*

MARTIN W. JOHNSON[1]

A CHARACTERISTIC FEATURE of the low-lying Alaskan coast of the Chukchi Sea is the presence of a more or less broken beadlike series of "lagoons" extending from Cape Prince of Wales to Point Barrow. The general scientific interest in these lagoons is succinctly summarized by R. H. Fleming and staff in a preliminary report on the "Brown Bear" cruise no. 236 in 1959:

> The geological and oceanographic processes that have led to development and life history of these features are of major scientific interest. Because each of them may represent a variable but unique micro-environment, the biology of these lagoons is also of unusual interest because they represent a transitional series of marine to freshwater environments. At one extreme these lagoons are, in effect, the complex estuaries of rivers that flow only during the summer. At the other extreme the older lagoons, now permanently isolated from the sea and clogged with sediment and vegetation, are only distinguishable from aerial photographs. Between these two extremes are bodies of water, varying greatly in size, that must from time to time be flooded with sea water and then are closed off again and slowly diluted by the accumulation of precipitation and runoff.

During August 4–15, 1959, an opportunity was provided by the U. S. Atomic Energy Commission's Committee for Environmental Studies of Project Chariot and the University of Washington Department of Oceanography[2] to conduct a survey of the plankton in a number of these more or less landlocked lagoons situated at the immediate coast in the region of Cape Thompson, Alaska. The samples collected, being from various lagoons, are important in providing a broad picture of the deviations or similarities that characterize the populations of these bodies of water. The fauna encountered are of special interest in furthering our knowledge of the geographic distribution, biology, and taxonomic status of certain calanoid copepod species that are in varying degrees transitional between the purely marine and freshwater forms.

Prior to the initiation of this project, there had apparently been no study of the zooplankton of these remote and relatively inaccessible lagoons. Some studies that provide especially useful records for comparison have been made previously of the offshore plankton of the Alaskan coast of the Chukchi and Beaufort seas (Willey, 1920; Johnson, 1953, 1956), and in ponds situated at Point Barrow (Comita and Edmondson, 1953; Comita, 1956; Johnson, 1958). Coincident with the present restricted study, a general plankton survey was made in the offshore waters of portions of Chukchi and Bering seas by members of the University of Washington Oceanographic Department aboard the "Brown Bear" (R. H. Fleming and staff, 1959).

It is a pleasure to thank Dr. Richard H. Fleming for providing this opportunity to participate in the research expedition of the University of Washington oceanographic vessel "Brown Bear" to the Chukchi Sea area. The assistance of Dr. Norman J. Wilimovsky, Philip Buscemi, and Howard Smith in the field is gratefully acknowledged, as is also the cooperation of the administrators and contractors of the project site. The water samples were titrated for chlorinity by the Geological Survey laboratory at the project camp site.

PROCEDURE AND RESULTS

The plankton samples were collected with a 30-cm. net, 1 m. long, constructed of no. 6 bolting cloth. An inflated rubber boat was used

[1] Scripps Institution of Oceanography, University of California, La Jolla, and the University of Washington, Department of Oceanography, Seattle. Contribution from Scripps Institution of Oceanography, New Series. Manuscript received September 12, 1960.

[2] Contract AT-45-1-540 and Nonr-477 (10).

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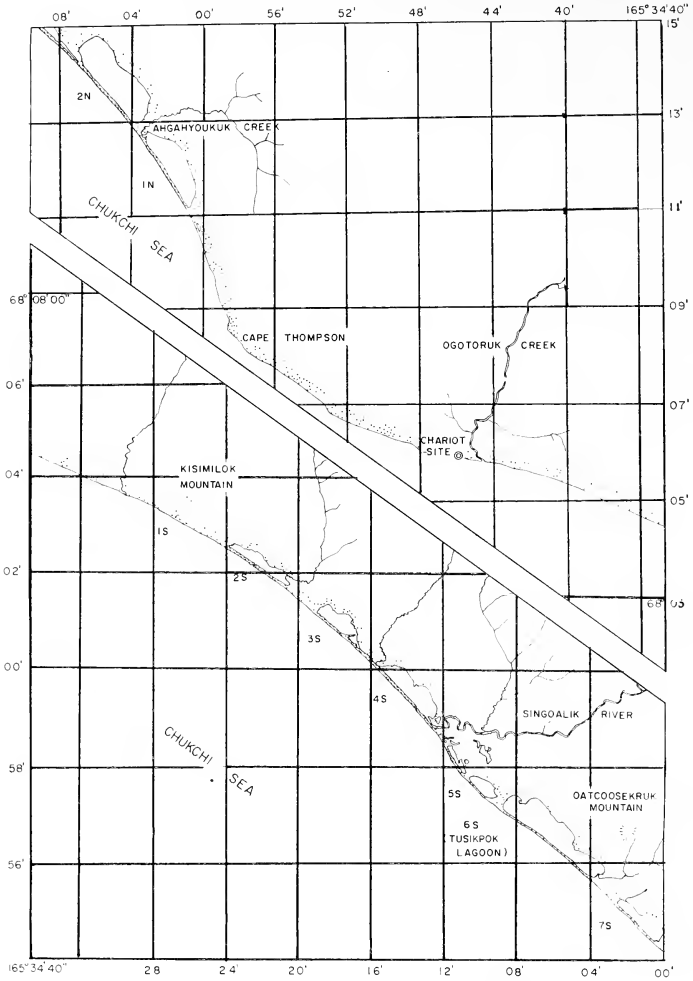


FIG. 1. Numbered lagoons sampled in the Cape Thompson, Alaska area. Based on U. S. Coast and Geodetic Survey Topographic Map T-9425 Alaska.

while obtaining the deeper hauls and the water samples. Most surface hauls were made by wading along shore with the net attached to the end of a pole.

Lagoons

The position, approximate size, and identification of the lagoons sampled are shown in Figure 1. Cape Thompson divides them geographically into a northern and a southern group, as numbered in Figure 1. The only lagoon for which a name occurs on U.S.C. and G.S. Topographic Map T-9423, on which Figure 1 is based, is Tusikpok, which corresponds to no. 6 south. All of the lagoons are shallow; the depths at the positions of sampling (about one-half the distance across the lagoon) were from 1.3 to 3 m., and, as anticipated from wind conditions and shallowness, they showed only moderate or no thermal or haline stratification except in no. 2 south where the salinity at the bottom was 1.65 per mille higher than that at the surface (Table 1). It is clear that they are at times subject to invasion of salt water from the sea. This is evidenced by the brackish water of some, by high wave-washed channels on the gravel berms separating the lagoons from the sea, and, in several instances, by the presence of marine and brackish water animals found in the plankton of some lagoons. Lagoons no. 2

TABLE 1

WATER TEMPERATURE AND SALINITY IN COASTAL LAGOONS IMMEDIATELY SOUTH AND NORTH OF CAPE THOMPSON, ALASKA, AUG. 1959

(The lower sample was taken just above the bottom depth indicated)

LAGOON	TEMP. °C.	SALINITY ‰
Lagoon no. 1 south, Aug. 12		
surface	11.0	0.83
bottom (1.5 m.)	11.0	0.83
Lagoon no. 2 south, Aug. 12		
surface	11.2	14.31
bottom (1.3 m.)	11.1	15.96
Lagoon no. 3 south, Aug. 12		
surface	11.0	0.16
bottom (2.1 m.)	10.4	0.17
Lagoon no. 4 south, Aug. 13		
surface	12.3	6.42
bottom (1.3 m.)	12.1	7.16
Lagoon no. 5 south, Aug. 13		
surface	13.6	0.83
bottom (1.3 m.)	13.6	0.83
Lagoon no. 6 south, Aug. 13		
surface	12.6	0.73
bottom (2.4 m.)	12.4	0.73
Lagoon no. 7 south, Aug. 13		
surface	12.6	3.58
bottom (2 m.)	12.1	3.58
Lagoon no. 1 north, Aug. 14		
surface	13.5	0.18
bottom (3 m.)	13.0	0.18
Lagoon no. 2 north, Aug. 15		
surface	13.8	0.46
bottom (2.5 m.)	13.0	0.55

and 4 south each have a narrow above-sea-level outlet that probably floods with sea water during high storms and undoubtedly accounts for the higher salinities observed there.

Judged by the composition of the contained zooplankton, the lagoons are strikingly dissimilar ecologically. How persistent this dissimilarity is cannot be said from this preliminary survey. Basically, the differences probably arise from the geographic position of each lagoon with respect to (1) extent of influx of fresh water in relation to the amount and frequency of that which spills over from the sea during high winds, (2) the height of the lagoon with respect to sea level, and (3) the effectiveness of the berm in serving as a barrier (reinforced by permafrost?) to water percolating out from the lagoon through the gravel. However, the environmental conditions characteristic of each lagoon have been sufficiently unique in the immediate past to permit selection and development of one or two species to a position of overwhelming dominance numerically, as shown by the analysis of the plankton fauna.

Zooplankton

The percentage composition of the fauna is shown in Table 2. Specific attention was given mainly to the calanoid copepods, because of the interest that some of the species hold as transitory forms or as permanent residents in the overlapping environmental conditions between the sea and fresh water. In all cases the populations were composed dominantly of fresh-water or brackish-water forms. But in lagoon no. 2 south, there was a conspicuous element of marine plankton, which was probably only recently recruited from the sea (Table 2). Although *Acartia bifilosa,* a brackish-water species, was overwhelmingly dominant in this lagoon, several marine copepods were also present, but no larval stages of any species were found that might indicate local production. However, if only one generation is produced each year in the lagoon, as is common in some Arctic lakes, the season of nauplii-hatching was probably about past. Most of the marine species found are considered typical of strongly neritic waters, but *Calanus finmarchicus, Pseudocalanus minutus,* and *Acartia longiremis* do also occur well offshore and are very common in the Chukchi Sea, especially off the eastern coast and well north into the Arctic.

Eurytemora pacifica is one of the more infrequent neritic species encountered. Rather little is known regarding its preferred habitat. Hitherto, on the Alaskan coast it has been taken only at Grantley Harbor, and in the region of Point Hope, where it was reported by Willey (1920) as *E. johanseni* n. sp. Excepting lagoon no. 2 south, it was not found in any of the present lagoons, but it was common in a tow taken immediately offshore from lagoon no. 1 north. It is also common in Kivalina Lagoon, where it constituted 7 per cent of the calanoids in a sample kindly provided by Mr. Robert W. Owen of

TABLE 2

PERCENTAGE COMPOSITION BY NUMBER OF PLANKTON IN COASTAL LAGOONS IMMEDIATELY SOUTH AND NORTH OF CAPE THOMPSON, ALASKA
(c = common; + = present, but neither in sufficiently large numbers to constitute 1 per cent of population)

	LAGOONS SOUTH														LAGOONS NORTH			
	1		2		3		4		5		6		7		1		2	
Date of sampling	6	12	6	12	6	12	6	13	6	13	6	13	6	13	14	15	5	15
Surface or bottom	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B
Arcartia bifilosa			78	90			90	12	c									
A. clausi			2						+									
A. longiremis			18	8														
Calanus finmarchicus			+															
Centropages abdominalis			c	+														
Cyclops spp.	65	12				+	+	4	c	c	2	c	+	+	c	1	1	+
Eurytemora canadensis	3					1		+	+	+	3		c	3				
E. herdmani			c	c														
E. pacifica			+	+														
E. foveola, n. sp.											95	90			99	98	57	28
Limnocalanus grimaldi															c	c		
L. johanseni	28	81			c	1	+		96	38		+	14	17	c	c	1	15
Pseudocalanus minutus			1	+														
Tortanus discaudatus			c	c														
Harpacticoids			+	1	+	+	5	72	+	+								
Daphnia	2	6			99	97	+		c	37	+	85	80				40	57
Podon			+	+			1	12										
Evadne			+				+	+										
Clam shrimp	2	1			+				3	25								
Fairy shrimp (Anostraca)	c																	
Ostracods		+		+		+	+				+							+
Neomysis (juvenile)								+										
Sagitta			+															
Fish larvae (total found)				3				7										
Rotifer												9						

the University of Washington from collections made near the outlet on Aug. 22, 1959. These are the only known locality records for the American coast. Elsewhere the species occurs on the Asian coast.

The other neritic species encountered are quite common in small numbers on the Alaskan coast to Point Barrow and in diminishing numbers eastward (Johnson, 1953, 1956).

In lagoon no. 4 south, the plankton was sparse and *Acartia bifilosa* was the most numerous copepod in the surface water on Aug. 6, but an unidentified harpacticoid was the dominant form at the bottom on Aug. 13. It is probably a benthic species since the net contained much bottom debris. Intermingled in the plankton on both dates were the neritic cladocerans, *Podon* and *Evadne*, as the chief evidence of marine invasion.

The plankton fauna of all of the remaining lagoons in the numbered series was characteristically fresh-water. However, there was still a strange marine affinity evidenced by the presence of *Limnocalanus grimaldi* and *L. johanseni*. The former species was common in lagoon no. 1 north, and the latter in all other lagoons with the exception of no. 2 south. The species of this copepod genus have long been the subject of much speculation with respect to their geographic distribution and affinities to the sea. One species, *L. macrurus*, commonly occurs in deep fresh-water lakes, and is generally believed to be a marine relict of glacial times. *L. grimaldi* is an Arctic marine and brackish-water form occurring along the Arctic coast of the U.S.S.R. and is also considered to be a relict of Arctic fauna when found in such widely different isolated localities as the Caspian Sea, the Gulf of Bothnia, and the Baltic Sea. Aside from its present occurrence in lagoon no. 1 north, it has been reported from the Alaskan coast on two previous occasions, once from a collection taken about 100 yd. from the shore at Collinson Point (Willey, 1920), and once at a series of nine offshore stations in the same region, and off the mouth of the Colville River (Johnson, 1956). The present discovery is therefore of special interest in extending the known range of the species on the Alaskan coast, and in recording its occurrence in virtually fresh water, together with *Eurytemora foveola* n. sp. that apparently thrives best at very low salinities.

Less is known about the distribution of *Limnocalanus johanseni*. It was originally described by Marsh (1920) from a fresh-water pond at Collinson Point, just inland from, but not connected with, the shore where Willey recorded *L. grimaldi*. Subsequently, Comita and Edmondson (1953) reported it from Imikpuk Lake, a fresh-water lake near Point Barrow. In the present survey it was a conspicuous element ranging from small to dominant numbers in all lagoons except no. 2 south, the one which most nearly approaches marine conditions. In lagoon no. 5 south, it was extremely abundant, and although a considerable number of early copepodid stages occurred mingled with adults no nauplii were observed. This agrees in general with the observations of Comita (1956) in a more extensive analysis which indicated that the eggs of this species in Imikpuk Lake hatched early in spring, and only copepodid stages are to be found in late July and August. His data show no nauplii after Jul. 31 and the first appearance of adults (copepodid stage VI) was on Aug. 10. In the present collections from lagoon no. 5, adults already outnumbered the other stages on Aug. 6, when the first sampling was done. Comita concluded that *L. johanseni* in Imikpuk Lake produces only one generation a year and that the species winters over in the egg stage. This agrees with the known life cycle of another fresh-water species, *L. macrurus*, discussed by Gurney (1931). Another similarity between the populations of Imikpuk Lake and lagoon no. 5 south was the presence of at least two size groups. This bimodality was not so pronounced in the males as in the females, but some tendency is shown (Fig. 2). The present analysis of the population applies only to the standing crop at the time of sampling, and hence further comparisons cannot be made other than to note that the large-size group was the most abundant. But it cannot be said whether they were produced before or after the small-size group.

TAXONOMIC NOTES

The following observations can be made regarding a few of the species encountered.

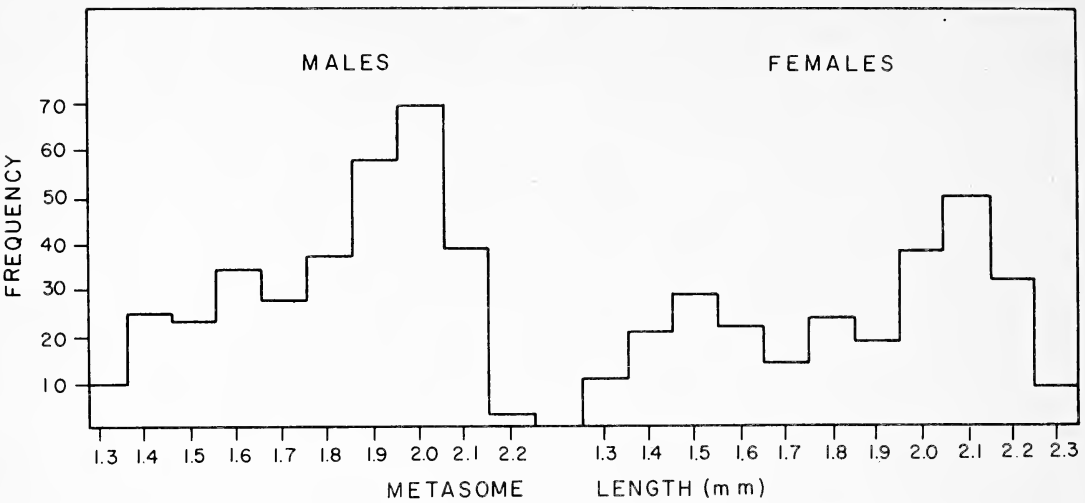


FIG. 2. Length frequency histogram for *Limnocalanus johanseni* adult (copepodid VI) population.

Limnocalanus grimaldi (de Guerne)

A total of 25 specimens was taken in lagoon no. 1 north, mostly near the bottom at a depth of only 3 m. Specimens were compared directly with *L. grimaldi* taken in 1950 in the Beaufort Sea at various stations offshore near Collinson Point and the Colville River. The fresh-water species *L. macrurus* Sars has not been seen for comparison. The Beaufort Sea specimens which were re-examined at this time agree well with the descriptions given in the literature for *L. grimaldi*. The head is not in the least vaulted as occurs in various degrees in *L. macrurus*, and there is only a slight cervical depression (Sars, 1897: pl. 4, figs. 2, 3, 17). The structure of the fifth feet also agrees. The first antennae of the female reach beyond the anterior margin of the anal segment. In the male there are five distinct segments in the distal end of the right antenna beyond the geniculation. The deviations from descriptions of *grimaldi* are mainly in the posterior margins of the fifth thoracic segment. These were smoothly rounded in some cases, but many specimens had the characteristic triangular or spine-like point, and this was sometimes present only on one side. The caudal rami were about eight times as long as broad and were slightly longer in relation to the urosome than given by Sars.

The specimens collected in lagoon no. 1 north are here also considered to be *L. grimaldi*, since they agree in nearly all respects with the Beaufort Sea material. The posterior margin of the fifth thoracic segment was acutely pointed in most specimens, but a few occurred with smoothly rounded margins (a characteristic of *L. macrurus*); there were, however, only four distinct segments in the distal end of the male right antenna beyond the geniculation. This is also a characteristic of *L. macrurus*, although Marsh (1933) states that in exceptional cases there may be five segments. The lagoon specimens were slightly smaller than those from the Beaufort Sea, namely 2.6 to 2.7 mm. as opposed to 2.9 to 3.3 mm. for females.

Since the condition of the fifth thoracic segment is obviously an unreliable character, one is left to choose between the relative specific value of the outline of the head, and the segmentation of the distal end of the male first antennae. Both of these are variable for *L. macrurus*. The habitat presented by lagoon no. 1 north is probably an important consideration, for although it was virtually fresh at the time and place of sampling, it is shallow and so near the sea that it may be reached by very high storm waves. This environmental situation may constitute an interesting natural experiment in which a landlocked population of *L. grimaldi*

has assumed some characteristics of its freshwater counterpart, particularly in the fusion of two of the segments in the distal portion of the male right antenna.

Limnocalanus johanseni Marsh

A comparison of specimens of this species from the lagoons and from collections I made in Imikpuk Lake in 1957 shows only small variations in structure. Mention should be made, however, of some features that are not included in the original description. It was noted that in many specimens the fifth thoracic segment may be smoothly rounded or with only slightly angular outline. Marsh states that this segment is rounded on the sides, and each side is armed with a small spine which may be either sharp or blunt. Apparently inadvertently omitted from Marsh's drawings is a long, heavy seta that occurs on the inner anterior distal angle of the second basis of the first feet.

Centropages abdominalis Sato 1913

Centropages mcmurrichi Willey 1920

Willey (1920) was apparently unaware of Sato's (1913) publication, and described this species as new under the name *C. mcmurrichi* n. sp. His description is without figures, but he considered the species to be identical with a copepod reported and figured by McMurrich (1916), with some reservations, as *C. hamatus* Lilljeborg. Examination of Alaskan material and reference to McMurrich's figures, and to those of Sato (photostatic copies of which are at hand through the courtesy of Dr. Takasi Tokioka and Isamu Yamazi of the Seto Marine Biological Laboratory), and of Mori (1937) leaves little doubt that these species are identical.

Eurytemora pacifica Sato 1913

Eurytemora johanseni Willey 1920

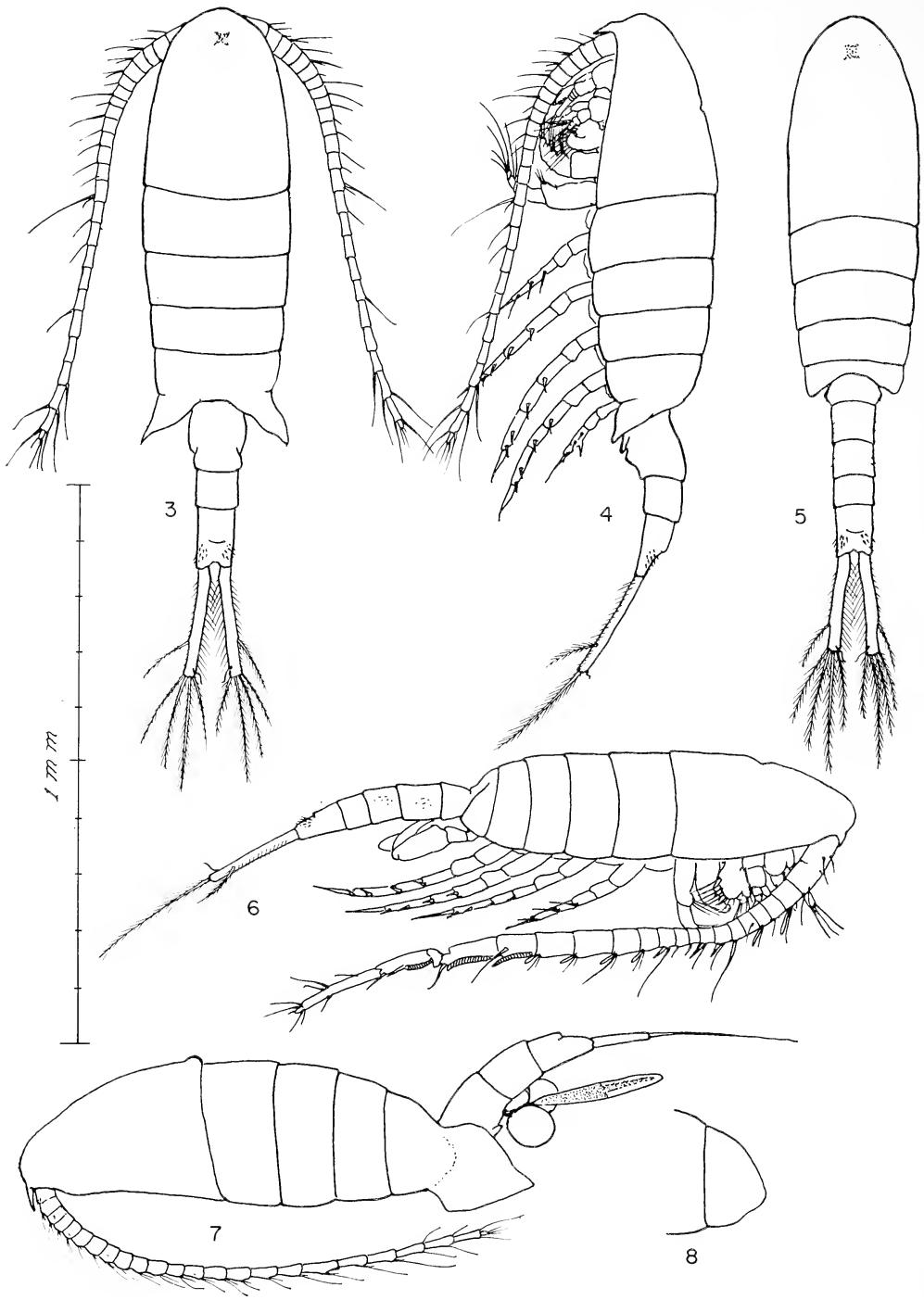
This is a clearly defined species, principally on the basis of the fifth feet in the female (Figs. 7–10). In the female, the fifth thoracic segment is provided with broad triangular wings, but breeding females were also found with this segment smoothly rounded (Fig. 8). The hyaline wing apparently may be shed or fails to develop. In the present study both males and females were found in the same catches. Willey (1920) described the species under the name *E. johanseni* n. sp. Sato described only the adult male, but his figures agree especially with Willey's figures 11 and 12 of the fifth feet. Smirnov (1931) first pointed out the probable identity of the species.

Eurytemora foveola n. sp.

TYPES: Holotype, male, U. S. National Museum no. 105996; allotype, female, USNM no. 105997. Type locality, lagoon no. 6 south.

In lagoon no. 6 south and nos. 1 and 2 north the dominant copepod was this hitherto unknown species. It was present in these lagoons in vast numbers and despite its small size constituted 90 per cent or more of the biomass in the samples from lagoon no. 6 south and no. 1 north where it was actively reproducing and many females were found carrying eggs and spermatophores. In lagoon no. 2 north it was greatly surpassed in mass by the larger cladoceran *Daphnia.* It is closely allied to *Eurytemora gracilis,* both sexes of which were described by Sars (1898) from the lower Yana (Jana) River and, judging from Sars' figures and description, the females may be nearly indistinguishable. The chief differences separating the present species from that of Sars' are structural details in the fifth feet of the males. In view of these small but apparently persistent differences, as shown by examination of a great many specimens, it seems best to designate it a new species rather than a variety of *E. gracilis.*

FEMALE (Figs. 3, 4): Length 1.15–1.25 mm. The body is slender in both dorsal and lateral aspects with about the following linear proportions: metasome (anterior division) 67, genital segment 11, first abdominal segment 6, anal segment 11, caudal rami 17. The metasome is slightly widest in the region of the first pedigerous segment. There is a slight cephalic depression, but no medial knob on the posterodorsal margin of the cephalic segment. (In *E. gracilis* the greatest width appears to extend somewhat farther forward according to Sars' pl. 8, fig. 8; and in his fig. 9, the lateral profile also differs in that his species is relatively thicker through the midbody and the cephalic



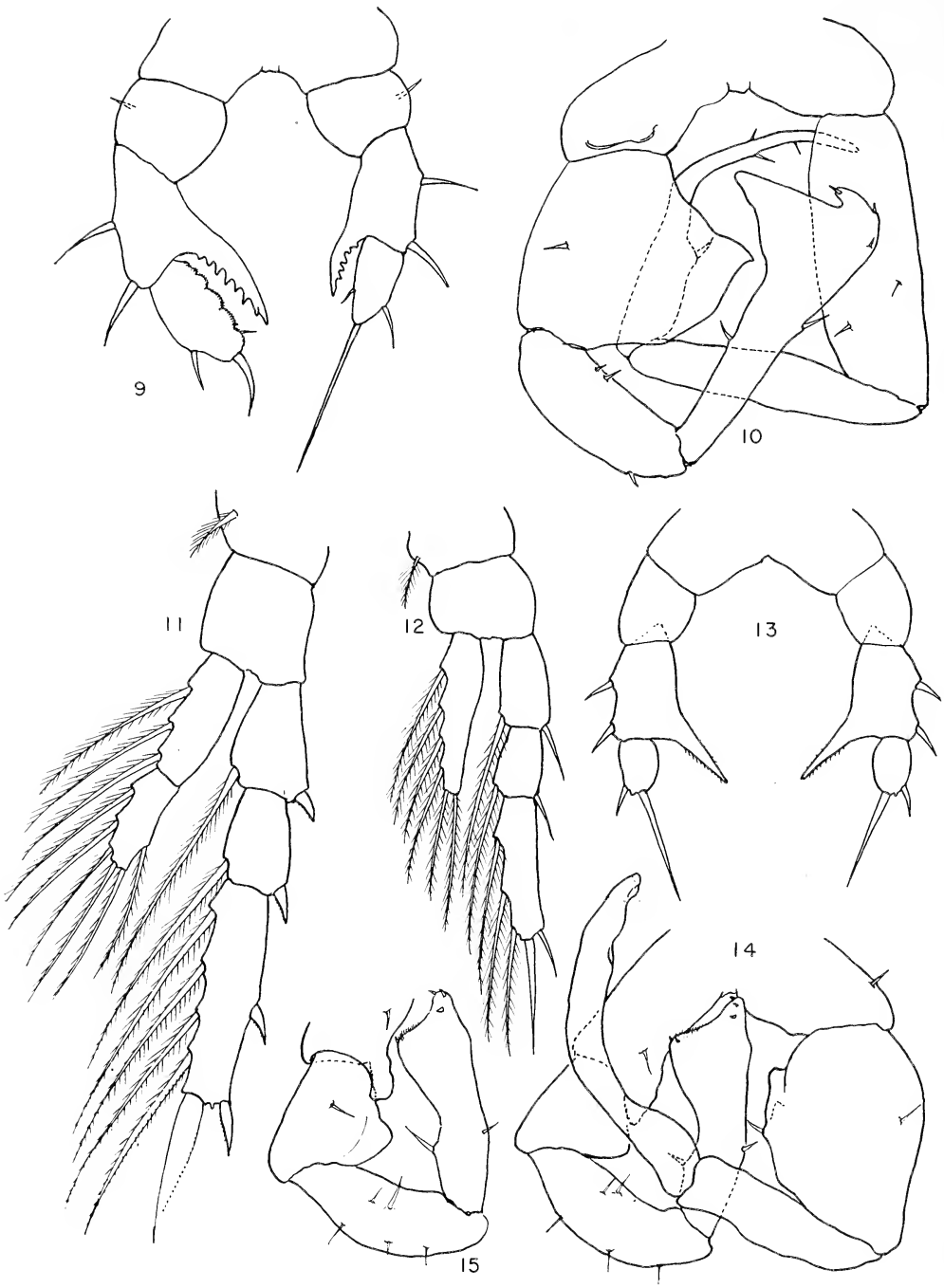
FIGS. 3–6. *Eurytemora foveola* n. sp. 3, Female, dorsal; 4, female, lateral; 5, male, dorsal; 6, male, lateral.

FIGS. 7–8. *Eurytemora pacifica*. 7, Female, lateral with eggs and spermatophore; 8, female, lateral outline of fifth thoracic segment occurring in some adults.

segment is slightly raised dorsally at the hind edge.) The fifth thoracic segment is extended into laterally projected "wings" that vary considerably in length and hyalinity. Many adult specimens were observed in which the left wing was only slightly developed, although the right wing was always well developed. The first antennae reach to, or slightly beyond, the fifth thoracic segment. The genital segment is nearly symmetrical and only slightly constricted laterally. It bears no lateral expansions but in lateral aspect has a rather conspicuous genital operculum. The anal segment is armed dorsolaterally with patches of fine spinules, best observed in aqueous media. (Sars states that in *E. gracilis* "the last caudal segment is perfectly smooth without any trace of the densely crowded spikes clothing the dorsal face of this segment in *T.* (*E.*) *hirundoides*.") The caudal rami are provided with fine "hairs" on both their inner and outer margins. The longest caudal setae are only slightly longer than the rami. The terminal spine of the exopod of the second, third, and fourth swimming feet (Fig. 11) is cultriform as in *E. gracilis*. The fifth feet (Fig. 13) are symmetrical as in *E. gracilis,* and the first exopod segment bears a heavy, slightly setose, unguiform process directed inward. There are two spines on the outer margin of this segment. The end segment is short and bears one long terminal spine and one short outer spine. The terminal spine of the exopod of the third and fourth feet is somewhat broadened in the middle and is shorter than the end segment. In the male this spine is longer and more slender. The genital operculum is rounded (Fig. 16) in contrast to the pointed operculum of the closely related species *E. affinis* as described and figured by Gurney (1931), and which he considers synonymous with *E. hirundoides*.

MALE (Figs. 5–6): Length 1.0–1.2 mm. The body is slender and nearly parallel-sided anteriorly but tapers posteriorly. The body proportions are about as follows: metasome 57, urosome (without caudal rami) 25, caudal rami 15. As in the female, the anal segment bears dorsal patches of tiny spinules. The caudal rami have fine "hairs" on the inner and outer margins. The right geniculated first antenna has 25 segments with moderately heavy spines on segments 8, 9, and 12. The fifth feet (Figs. 14, 15) are asymmetrical, uniramous, and each exopod consists of two segments. The specific characters separating the species from closely related forms are seen mainly in the basal segments and in the relative proportions of the segments of the rami. At the inner proximal margin of the second basipod of the right foot there is a well-defined rounded projection and associated smooth notchlike depression suggesting the specific name. The inner margin of the first basipod of the left foot projects downward, forming an irregular blunt process overlapping about one-third the length of the second basipod. The second basipod is broadened with an inward expanse forming a dull flange along the long axis of the segment. Sars' plate 8, figure 16, shows no trace of these three features for *E. gracilis*. Otherwise the exopod segments agree with that species which, however, appears to have a shorter first exopod segment on the left foot. The uncertain species described by Kiefer (1938) also differs in the absence of these characters and in the shape of the second basal segments of each foot. The second antennae and the mouth appendages of *E. foveola* are similar in the two sexes and appear to have no specific character except perhaps for the shape of the mandibular blade (Fig. 17). Few illustrations of other species are available with which to make comparisons, but the gap between the first and second tooth is considerably wider than that figured by Gurney (1931) for *E. affinis*, Sars (1903) for *E. velox*, and Wilson (1953) for *E. yukonensis* and *E. composita*.

It should be mentioned that a single damaged female specimen of a *Eurytemora* was collected by the Canadian Arctic Expedition offshore near Cape Thompson. Willey (1920) tentatively referred it to *E. gracilis*. It is not possible to conclude what species he dealt with but the proximity of the catch to the lagoons so richly populated by *E. foveola* makes it highly likely that it had been washed out from a nearby lagoon. Although there may be an intermittent present-day connection between the Yana River population and that in the Cape Thompson area, it must be a very tenuous one for a fresh- or brackish-water species, especially in view of the prevailing oceanic circulation northward through



FIGS. 9–10. *Eurytemora pacifica.* 9, Female, fifth feet; 10, male, fifth feet.

FIGS. 11–15. *Eurytemora foveola* n. sp. 11, Female, fourth foot; 12, female, first foot; 13, female, fifth feet; 14, male, fifth feet; 15, male, left fifth foot.

the Bering Strait and eastern Chukchi Sea. However, other studies indicate that plankton organisms may be transported across rather well-defined currents by eddy diffusion, and the prevailing currents along the Siberian coast might bring expatriates into the western portion of the Chukchi Sea. Brodskii (1950) does not include *E. gracilis* in his list of copepods of the Polar Basin.

Gurney (1931) has pointed out the specific variabilities that may occur in several species of *Eurytemora* living in different habitats in Europe. It remains to be shown to what extent *E. foveola* may also be morphologically variable in diverse environments. The great range of Alaskan lagoon and estuarian habitats and the seven or more species on the Alaskan coast should provide excellent material for such a study.

SALINITY RELATIONS

Although the data are too few to give more than a glimpse into the salinity tolerances observed for the various copepod species identified, still it is worthwhile to record such analyses as can be made from this area. Figure 19 appears to divide the copepods encountered into three groups with respect to salinity range and preference. (1) *Acartia bifilosa* and *A. clausi* occurred over nearly the whole range encountered but not below 0.83 ‰ at which value only relatively few specimens were found, especially *A. clausi*. The former was the dominant copepod in the two lagoons having highest salinities 6.42 to 15.96 ‰. (2) *Cyclops* spp., *Eurytemora canadensis*, and *Limnocalanus johanseni* ranged from 0.16 to about 7 ‰ but appeared to thrive best at 0.73 to 0.83 ‰. *Eurytemora foveola* n. sp. probably belongs to this group but stands somewhat alone in occurring only in ranges from 0.18 to 0.73 ‰ at which salinities it was dominant. *Limnocalanus grimaldi,* in this unique situation, occurred also at only a very low salinity, but elsewhere in the arctic it has a strong affinity for the sea. (3) The final group, into which *Acartia bifilosa* and *A. clausi* extended, are the characteristically marine forms occurring in lagoon no. 2 south with salinities of 14.31 to 15.96 ‰. Only in the more saline lagoons, nos. 2 and 4 south, was there any appreciable range in salinity from top to bottom. These two lagoons are also probably the ones most readily invaded by marine forms, but the influx of fresh water appears also to be quite high in these lagoons. Hence the communities are probably more or less transitory and fluctuate with repeated recolonizations.

Whittaker and Fairbanks (1958) have studied the occurrence of various nonmarine copepods in inland lakes and ponds of different salt content. The salinities and fauna they dealt with are of course not directly comparable with those of coastal lagoons, since the ratio of salts differ and their more saline species have different taxonomic relationships. But it is interesting to note that the transition between saline and fresh-water communities in their study was "somewhere between 425 and 875 ppm" for most bodies of water. If a comparison is justified it must be with the fresh-water fauna of the lagoons, then lagoons nos. 1, 3, 5, and 6 south and 1 and 2 north could be expected to foster truly fresh-water species and the occurrence of *Eurytemora canadensis* and *Limnocal-*

FIGS. 16–18. *Eurytemora foveola* n. sp. 16, Female, genital field and operculum, ventral; 17, male, mandibular blade; 18, male, labrum.

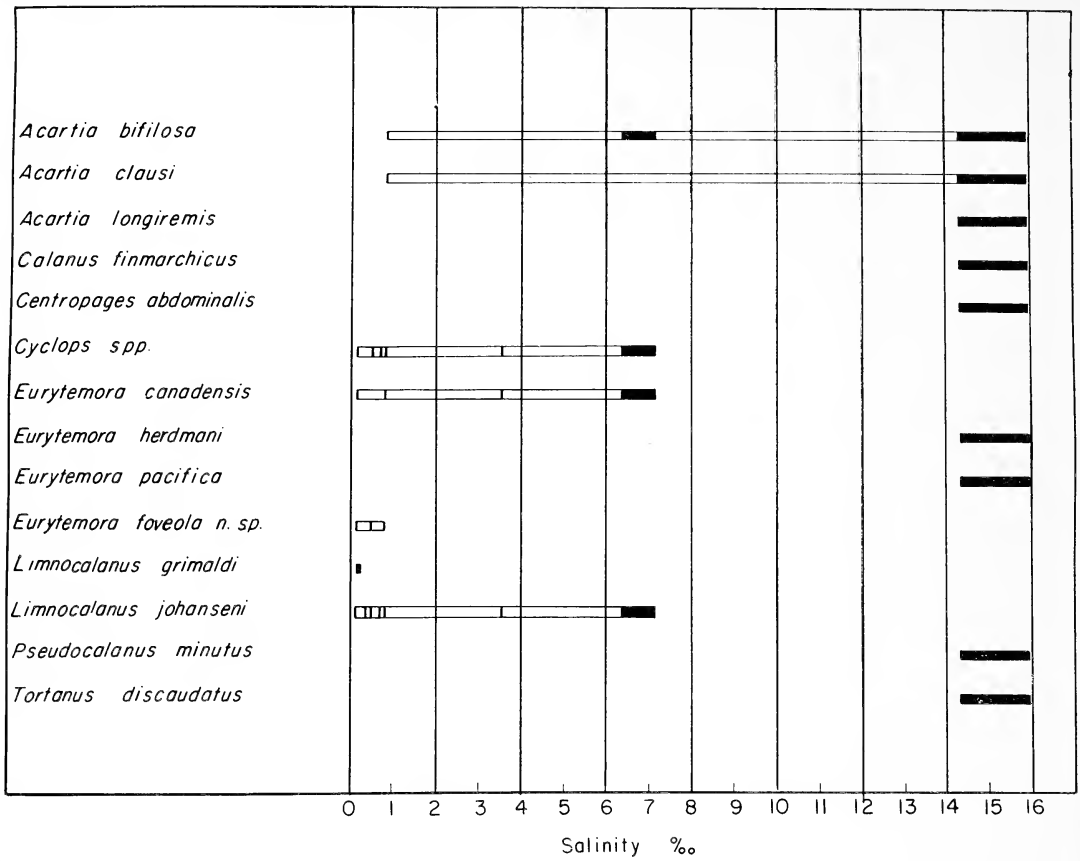


FIG. 19. Total salinity ranges over which certain copepod species occurred in nine coastal lagoons near Cape Thompson, Alaska, 1959. Cross bars denote salinity at stations of sampling.

anus johanseni in most of these and in lagoons nos. 4 and 7 south would mark them as quite euryhaline but with preferences for the lower salinities.

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Revision of the Genus *Pandanus* Stickman, Part 3
A New Species from Oeno Island, Tuamotu Archipelago

HAROLD ST. JOHN[1]

PREVIOUS PARTS of this revision of *Pandanus* have appeared in *Pacific Science.* A single species is here published in order that its name may be available for use in another projected publication.

PANDANACEAE (SECTION *Pandanus*)

Pandanus feruliferus sp. nov.
Fig. 11

DIAGNOSIS HOLOTYPI: Arbor 10 m. altus 30 cm. diam. corona rotundata, foliis longioribus 92 × 5.4 cm. longe diminuentibus in basi paene latioribus subcoriaceis, nervo medialein parte tertia infera inerme in media cum dentibus acicularibus luteis adpressis 1.5–2 mm. longis 14–38 mm. distantibus in parte tertia ultima dentibus nigris 1 mm. longis 1.5–4 mm. distantibus, marginibus in basi inermibus sed in parte quarta infero cum dentibus subulatis luteis adpressis 2–2.5 mm. longis 2–7 mm. distantibus in parte media simulantibus sed nigris in parte quarta ultima ad eos marginis simulanties, syncarpio terminale, phalangibus 6–6.2 cm. longis 2.3–3.7 cm. lotis 2.1–3 cm. crassis oblanceo-ellipsoideis paene compressis epiderme

[1] B. P. Bishop Museum, Honolulu 17, Hawaii, U.S.A. Manuscript received December 12, 1959.

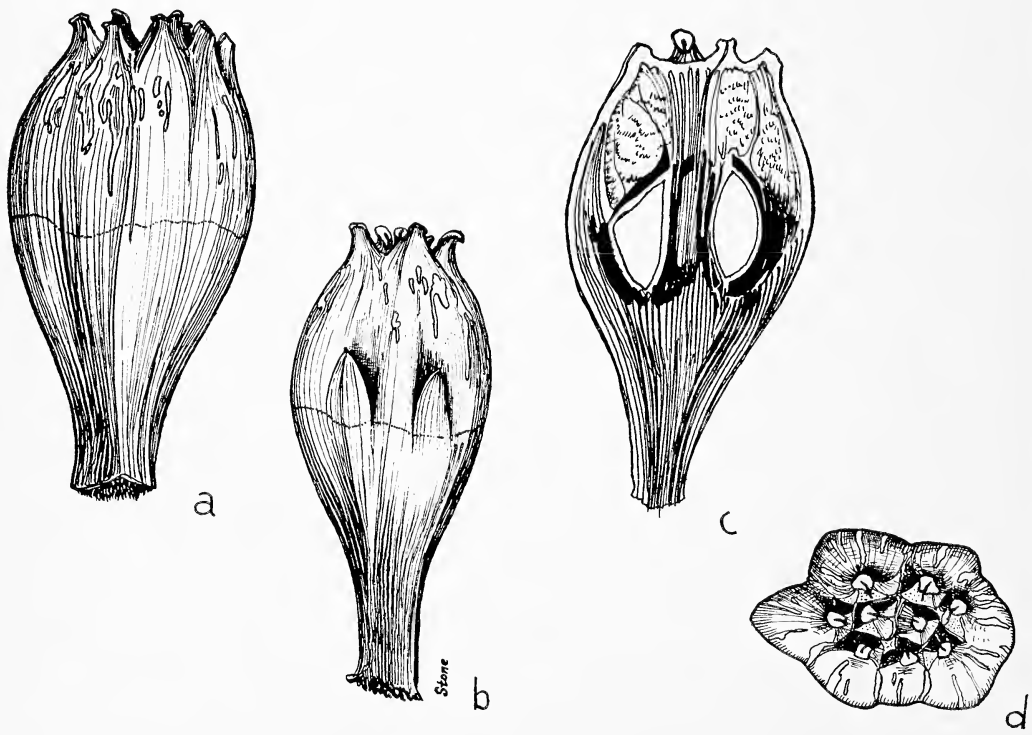
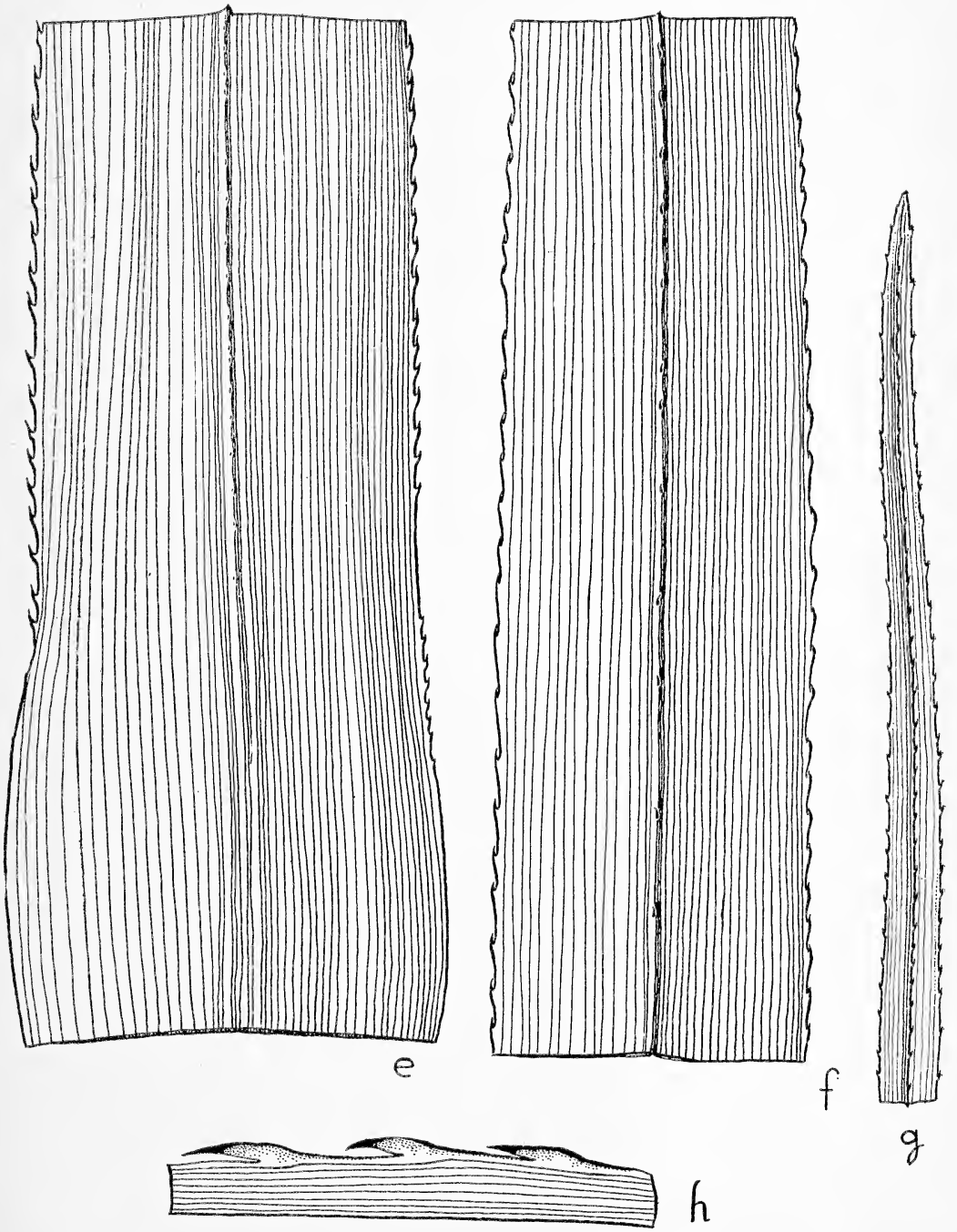


FIG. 11. *a, b,* Phalange, lateral view, × 1; *c,* phalange, longitudinal median section, × 1; *d,* phalange, apical view, × 1; *e,* leaf base, lower side, × 1; *f,* leaf middle, lower side, × 1; *g,* leaf tip, lower side, × 1; *h,* marginal teeth of leaf near base, × 4.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in sicco brunneo lucido cum 5–8 angulis eprominentibus lateribus laevibus lucidis subplanosis sinibus lateribus subcausis dimidia supera libera apice convexo et 7–24 mm. lato, apicibus liberis carpelorum anguste conicis eis centralibus erectis sed eis marginis extus curvatis sinibus centralibus 3–5 mm. profundis, 40% phalangiorum cum 1–3 carpelis lateralibus parvis abortivis et 40% minoribus, carpellis 5–11; stigmatibus apicalibus 2–3 mm. longis suborbicularibus vel ovatis fissis centripetalibus in 45° obliquis, mesocarpio apicale fibroso et cavernoso, mesocarpio basale fibroso et carnoso, endocarpio mediale osseoso obscure mahogani-brunneo gracile 1–2 mm. crasso, seminibus 12–16 mm. longis 5–7 mm. latis oblique ellipsoideis.

DIAGNOSIS OF HOLOTYPE: Tree 10 m. tall, 30 cm. in diameter, round-topped; longer leaves 92 cm. long, 5.4 cm. wide, ligulate, long tapering to an apparently acute apex, at basal attachment only slightly broadened, subcoriaceous, the midrib unarmed on the lower third, near the middle with ascending yellowish acicular appressed teeth 1.5–2 mm. long, 14–38 mm. apart, on the upper third the teeth 1 mm. long, 1.5–4 mm. apart, black; the margins at base unarmed, near the lower quarter the teeth 2–2.5 mm. long, 2–7 mm. apart, appressed subulate yellowish; those near the middle similar but black; those of the upper quarter like those on the adjacent margins; heads terminal, size and shape not recorded; phalanges 6–6.2 cm. long, 2.3–3.7 cm. wide, 2.1–3 cm. thick, oblance-ellipsoid, a little compressed, the surface (when dried) brown, smooth, shining, with 5–8 slight angles, the sides shining, smooth, nearly plane, the sutures between the lateral carpels mostly invisible, only a few of them with distinct furrows about half as long as the phalange, upper half free and marked with numerous longitudinal light-colored cracks, the sides curving upward like an ellipse, the apex convex and 7–24 mm. wide, the free carpel apices narrowly conic, the central ones erect, the marginal ones curved, diverging, the central sinuses 3–5 mm. deep; of the phalanges 2/5 show 1–3 small abortive lateral carpels about 2/3 as long as the fertile ones; carpels 5–11; stigmas apical, 2–3 mm. long, suborbicular to ovate, creased, centripetal, oblique, at about 45° facing the center; apical mesocarp fibrous and cavernous; basal mesocarp fibrous and fleshy; endocarp median, bony, dark mahogany brown, forming a thin coating only 1–2 mm. thick; seed 12–16 mm. long, 5–7 mm. wide, oblique ellipsoid.

HOLOTYPUS: Oeno Island, Tuamotu Archipelago, forest on coral sands, 3 m. alt., June 23, 1934, *H. St. John & F. R. Fosberg 15,197* (BISH).

In the Bishop Museum there is another collection from Oeno, 1922, *E. H. Quayle 410*. The leaf has larger, coarser, more widely spaced, marginal teeth. It might be a leaf from a vigorous seedling of this species, but the collection lacks fruit, so it will be left undetermined.

A similar plant is *P. odoratissimus* L. *f.* var. *oahuensis* Martelli from Hawaii, but this has phalanges 6.5 cm. long; and the carpel apices inflexed and low, broad pyramidal.

More similar is *P. Mei* F. Br. which has phalanges 7 cm. long, 2.5 cm. wide, the six carpels with apices convex; stigmas 4 mm. in diameter, reniform, horizontal; endocarp walls 2.5–5 mm. thick. This occurs on Hivaoa, Marquesas Islands.

The specific epithet is coined from the Latin, *ferula,* a splint; *fero,* to bear. It is formed in analogy to the splints or vestigial digit bones in a horse's leg, since the *Pandanus* phalanges often bear abortive marginal carpels, suggestive of the splint bones of a horse.

Revision of the Genus *Pandanus* Stickman, Part 4
Disposition of Some Later Homonyms

HAROLD ST. JOHN[1]

Pandanus glauciferus St. John, nom. nov.

P. glauciphyllus C. B. Robinson, Torrey Bot. Cl. Bull. 35: 64, 1908, non *P. glaucophyllus* Ridl., Asiat. Soc. Str. Br. J. 41: 50, 1904.

Under the 1956 International Code, Rec. 73G and Art. 73 Note 2, the epithet *glauciphyllus,* differing only in the connecting vowel, and *i* being an incorrect one, is an orthographic error. The epithet *glauciphyllus* must be treated as a later homonym and under Art. 64(2) must be rejected. Hence, a new name for it is provided.

Pandanus compressus Martelli, Webbia 1: 363, 1905; 4(1): table 10, figs. 14–15, 1913.

P. tetrodon Balf. *f.* ex Kanehira, Bot. Mag. Tokyo 52: 236–239, fig. 70, 1938, avowedly by (Gaud.) Balf. *f.,* based on *Barrotia tetrodon* Gaud., non *P. tetrodon* Ridl., R. Asiat. Soc. Str. Br. J. 68: 13–14, 1915.

The genus *Barrotia* Gaud. was published in 1841 in the botanical atlas of the voyage of "La Bonite." The new genus was not given a description, and since it contained three species, the genus and its species are invalid and these cannot be adopted or transferred. Balfour in 1878 printed the combination *P. tetrodon* (Gaud.) Balf. *f.,* but did not accept it himself. Hence, *P. tetrodon* Balf. *f.* ex Kanehira dates only from 1938 and is a later homonym of *P. tetrodon* Ridl. Kanehira attempted to solve the problem by renaming *P. tetrodon* Ridl. as *P. singaporensis* Kaneh. (1938), but this action was illegal, and Ridley's species stands.

For *P. tetrodon* Balf. *f.* ex Kanehira there is an available, legitimate name: *P. compressus* Martelli, based on a collection from the Solomon Islands.

[1] Faculté des Sciences, Université de Saigon, Vietnam. Manuscript received April 1, 1960.

Revision of the Genus *Pandanus* Stickman, Part 5
Pandanus of the Maldive Islands and the Seychelles Islands, Indian Ocean

HAROLD ST. JOHN[1]

THE MALDIVE ISLANDS form a western fringe of atolls off the coast of India and Ceylon. Their flora was summarized by J. C. Willis and J. S. Gardiner (1901), but *Pandanus* has not received particular attention. They recorded *Pandanus* on many of the atolls, and described their utilization for mats, pillows, sails, and for food. Three species were listed: *P. odoratissimus* L. *f.*, *P. Leram* Jones *ex* Fontana with the doubtful synonym (*? P. Hornei* Balf. *f.*), and *P.* sp. indet. The present writer considers the first to be a misidentification with the Ceylonese species; the second, *P. Leram,* is confined to the Andaman and Nicobar Islands, and the Maldive plant is doubtless the new *P. Fosbergii* St. John, and the third remains undetermined. Four additional species of the affinity of *P. odoratissimus* are here described.

Dr. F. R. Fosberg in 1956 observed and collected *Pandanus* on several of the islands. He identified (1957: 11) them as *P. odoratissimus.* His no. 36,916 is here described as *P. maldivecus* St. John; and his no. 36,899 as *P. Fosbergii* St. John.

Dr. W. D. Hartman was a member of the Yale University 1957 Expedition to the Indian Ocean. From his excellent collections there are here described several new species.

Hartman also visited the Chagos Archipelago, but on his brief land excursions he found no *Pandanus.*

SEYCHELLES ISLANDS

The flora of these islands is well known and was well presented by Baker (1877). From the islands we know *P. Balfourii* Martelli, *P. Hornei* Bory, *P. multispicatus* Balf. *f.*, and *P. sechellarum* Balf. *f.* Of these, Hartman in 1957 collected all but the third, and his complete specimens allowed supplements to the previously published descriptions.

For Aldabra Atoll, J. C. F. Fryer (1912: 402) recorded *P. Vandermeeschii* Balf. *f.* in Baker, a species now considered endemic to Mauritius. The Aldabra specimens are in need of further revision, and the writer has not seen them as yet.

Pandanus OF THE MALDIVE ISLANDS

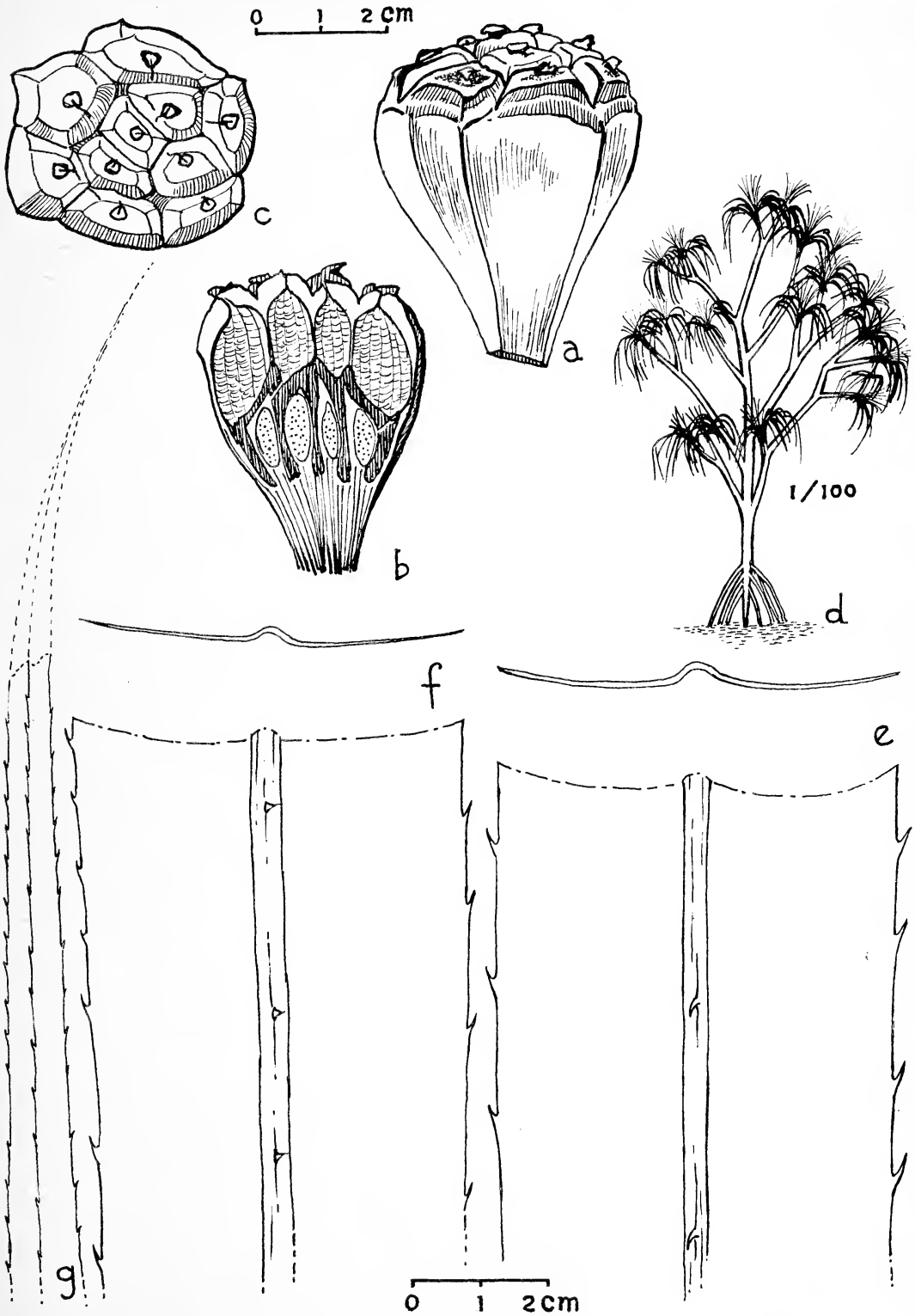
Pandanus adduensis sp. nov. (sect. *Pandanus*) Fig. 12

NOM. VERN.: "karikayo."

DIAGNOSIS HOLOTYPI: Arbor 6–7 m. alta, corona late ovoidea, radicibus fulturosis evidentibus, foliis 150 cm. longis 6.3 cm. latis firme subcoriaceis ligulatis apice gradatim longe acuminatis apice ultimo non viso ad basem M-formatis, marginibus in regione basali cum aculeis 3–4 mm. longis 12–22 mm. distantibus adscendentibus forte subulatis cum basibus incrassatis et apicibus obscure brunneis midnervio proximo infra cum aculeis 2.5–3 mm. longis 11–30 mm. distantibus reflexis crasse subulatis cum basibus incrassatis, in regione mediali marginibus cum aculeis 2–3 mm. longis 8–22 mm. distantibus subulatis in 30° adscendentibus, midnervio proximo infra inermi; in regione apicali aculeis 0.4–0.6 mm. longis crasse subulatis in 45° adscendentibus eis marginalium 3–5 mm. distantibus illis midnervi 5–10 mm. distantibus adscendentibus, phalangibus 4.5–4.9 cm. longis 3.4–4.1 cm. latis 3–3.7 cm. crassis obovoideis basi cuneata apice valde convexo, parte ¼ supera libera lateribus laevibus lucidis in sicco brunneis fere planatis anguste

[1] B. P. Bishop Museum, Honolulu 17, Hawaii, U.S.A. Manuscript received May 20, 1960.

FIG. 12. *Pandanus adduensis,* from the holotype. *a,* Phalange, lateral view, × 1; *b,* phalange, longitudinal section, × 1; *c,* phalange, apical view, × 1; *d,* tree, × 1/100; *e,* leaf base, lower side, × 1; *f,* leaf middle, lower side, × 1; *g,* leaf apex, lower side, × 1.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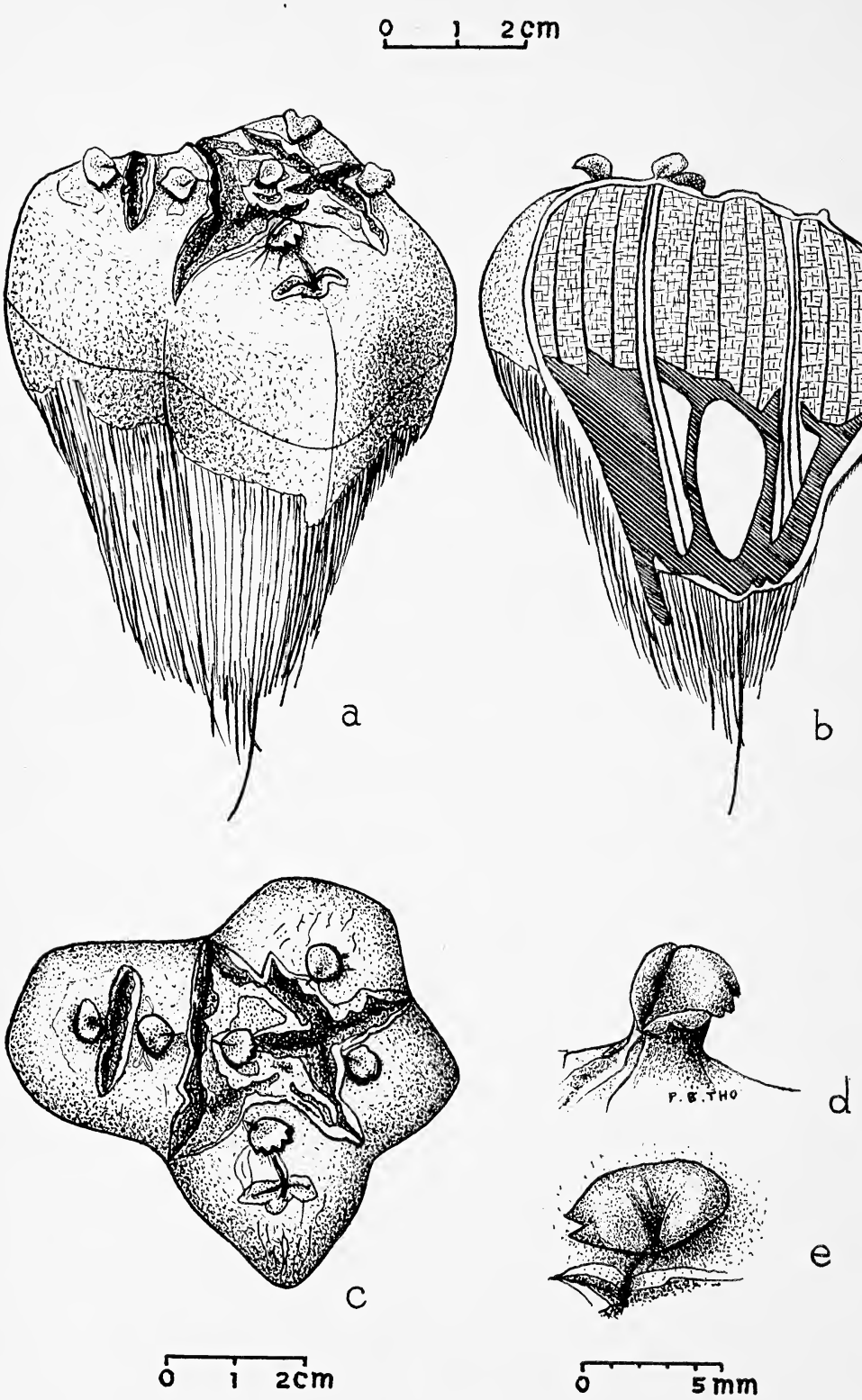
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6–7-angulosis, suturis lateralibus nullis, sinibus apicalibus centralibus 3–4 mm. profundis V-formatis (phalangiis geminatis 5–5.5 cm. latis et carpellis 18–22), carpellis 9–13, apicibus humiliter pyramidalibus eis centralibus valde oblatis illis marginalibus late distali truncatis et etiam concavis, stigmatibus 2.5–4 mm. longis cordatis vel irregulariter ellipticis oblique inclinatis centripetalibus, sutura proximali ⅓–½ distancia ad fundum extenta, endocarpio paene submediali osseoso obscure brunneo marginibus lateralibus 2 mm. crassis, seminibus 8–10 mm. longis 3.5–5 mm. diametro oblique ellipsoideis, mesocarpio apicali in quaque carpella cavernoso cum fibris longitudinalibus et membranis medullosis, mesocarpio basali fibroso.

DIAGNOSIS OF HOLOTYPE: Tree 6–7 m. tall; crown broad ovoid; prop roots present; leaves 150 cm. long, 6.3 cm. wide, firm subcoriaceous, M-shaped in cross-section, ligulate, the apex gradually long acuminate, but the tip not seen, the margins near the base with prickles 3–4 mm. long, 12–22 mm. apart, stout subulate, broad based, ascending, dark brown tipped; the nearby midrib below with prickles 2.5–3 mm. long, 11–30 mm. apart, reflexed, stout subulate from an enlarged base; at the midsection the margins with prickles 2–3 mm. long, 8–22 mm. apart, subulate, ascending at 30°; the midrib unarmed; near the apex the margins and midrib below with ascending prickles 0.4–0.6 mm. long, stout subulate, ascending at 45°, those of the margin 3–5 mm. apart, but those of the midrib 5–10 mm. apart; phalanges 4.5–4.9 cm. long, 3.4–4.1 cm. wide, 3–3.7 cm. thick, obovoid with the base cuneate and the apex convex, upper ¼ free, the sides smooth, shining, brown when dry, almost plane, sharply 6–7-angled, lateral sutures none; central apical sinuses 3–4 mm. deep, V-shaped; (phalange twins 5–5.5 cm. wide and with 18–22 carpels); carpels 9–13; carpel apices low pyramidal, the central ones strongly oblate, the marginal ones broad truncate and even concave distally from the stigma; stigmas 2.5–4 mm. long, cordate or irregularly elliptic, oblique, centripetal; proximal suture running ⅓–½ way to valley bottom; endocarp slightly submedian, bony, dark brown, the lateral margins 2 mm. thick; seeds 8–10 mm. long, 3.5–5 mm. in diameter, obliquely ellipsoid; apical mesocarp in each carpel a cavity with longitudinal fibers and pithy partitions; basal mesocarp fibrous.

HOLOTYPUS: Maldive Islands: Addu Atoll, Hitadu Islet, near shore, common, Oct. 13, 1957, *W. D. Hartman 4* (Arn. Arb.).

DISCUSSION: *P. adduensis* is a member of the section *Pandanus.* In that section its close relative is an undescribed species from Papua, *St. John 26,234,* which has the phalange upper third free, the apex low convex; carpel apices rounded pyramidal, the outer ones with an oblique outer plane surface reaching only to the stigma; stigmas 1–2 mm. long, ellipsoid; bark with papillae developing ascending rootlets. *P. adduensis* has the phalange with the upper quarter free, its apex convex; carpel apices low pyramidal, the marginal ones broad truncate and even concave distally from the stigma; stigmas 2.5–4 mm. long, cordate or irregularly elliptic; and the bark lacking ascending rootlets.

The new epithet is made of *Addu,* the type locality; and *-ensis,* the Latin adjectival place ending.

Pandanus Fosbergii sp. nov. (sect. *Pandanus*)
Figs. 13–14

NOM. VERN.: "karikio."

DIAGNOSIS HOLOTYPI: Arbor 6–8 m. alta, foliis 3–4 ("ad saltem 4") m. longis 11–13 cm. latis firmis spongioso-coriaceis minime M-formatis in sectio ligulatis sed ad apicem constrictis in apice (acuto?), basi amplexicaule exarmatis per 10 cm. deinde marginibus grosse subulato-serratis serris 3.5–5 mm. longis 10–25 mm. distantibus in apice brunneis, midnervio infra cum serris simulantibus 3 mm. longis 15–30 mm. distantibus reflexis, in regione mediali marginibus cum serris 3–4 mm. longis 7–17 mm. distantibus grosse subulatis adpresse adscendentibus, midnervio infra salienti et cum dentis sumulantibus adscendentibus 4–8 cm. distantibus, proxima apice marginibus subulato-

FIG. 13. *Pandanus Fosbergii,* from holotype. *a,* Phalange, lateral view, × 1; *b,* phalange, longitudinal section, × 1; *c,* phalange, apical view, × 1; *d, e,* stigmas, oblique view, × 4.

serratis dentibus 1 mm. longis 1.5–3 mm. distantibus adscendentibus, midnervio cum serris simulantibus sed 3–13 mm. distantibus, pedunculo circa 30 cm. longo trigono folioso, bracteis longe subulato-acuminatis et cum spinis simulantibus, syncarpio "oblongo scilicet 3 dm. longo 1.5 dm. diametro," phalangibus 8.7 cm. longis 6.2 cm. latis 5.2 cm. crassis late cuneiformibus sed in sectio transversali trigono, apice subconvexo, parte ⅓ supera libera, suturis lateralibus nullis, lateribus laevibus gradatim convexis in sicco pallide brunneis obtuse 3–4-angulosis, sinibus centralibus apicalibus nullis suturis tantum lineis superficielibus tessellatis sed in post maturite cum rima lata, carpellis 6, apicibus subconvexis non protensis, stigmatibus 4–5 mm. longis suborbicularibus vel obreniformbus centripetalibus tota elevatis obliquis, sutura proximali plerumque ad suturam extenta, endocarpio mediali 3–4 cm. longo osseoso obscure brunneo superficie interiori lucida, marginibus lateralibus 2–3 mm. crassis, seminibus 2.2–2.4 cm. longis 11 mm. diametro anguste obovoideis, mesocarpio cum cavernis subdistinctis cum fibris et medulla firma persistenti, mesocarpio basali fibroso et carnoso et dicet esculenti.

DIAGNOSIS OF HOLOTYPE: Tree, up to 6–8 m. tall, large stemmed; leaves 3.4 "to at least 4" m. long, 11–13 cm. wide, firm, spongy coriaceous, slightly M-shaped in cross-section, ligulate, but near the apex narrowed to the (acute?) tip, the base amplexicaul, unarmed for about 10 cm., then the margins coarsely subulate serrate, the teeth 3.5–5 mm. long, 10–25 mm. apart, brown-tipped, the midrib below with similar teeth 3 mm. long, 15–30 mm. apart, reflexed; at the midsection the margins with the teeth 3–4 mm. long, 7–17 mm. apart, heavy subulate, appressed ascending, the midrib below salient and with similar, ascending teeth 4–8 cm. apart, near the apex the margin with teeth 1 mm. long, 1.5–3 mm. apart, subulate-serrations, the midrib below with similar teeth but these 3–13 mm. apart; peduncle about 30 cm. long, trigonous, leafy bracted, the bracts similarly spiny, and long subulate acuminate; syncarp "oblong, at least 3 dm. × 1.5 dm., but none seen mature"; phalange 8.7 cm. long, 6.2 cm. wide, 5.2 cm. thick, broad cuneiform, but trigonous in cross section, the apex low convex, upper ⅓ free, lateral sutures none, the sides smooth, gently convex, pale brown when dried, with 3–4 obtuse angles; apical central sinuses none, the suture lines merely superficial and tessellate; in post maturity a broad crack develops near each sutural region; carpels 6, their apices low convex, not projecting; stigmas 4–5 mm. long, suborbicular to obreniform, centripetal, wholly elevated and oblique; proximal crease running quite or nearly to the sinus line; endocarp median, 3–4 cm. long, bony, dark brown, the inner walls polished and shining, the lateral walls 2–3 mm. thick; seeds 2.2–2.4 cm. long, 11 mm. in diameter, narrowly obovoid; apical mesocarp of scarcely distinct caverns, with longitudinal fibers and a firm, persistent medullary tissue; basal mesocarp fibrous and fleshy, reported to be edible.

HOLOTYPUS: Maldive Islands: Malé Atoll, Kuda Bados Islet, occasional in coconut plantation, 1 m. alt., key picked up on ground nearby, April 1, 1956, *F. R. Fosberg 36,899* (US).

DISCUSSION: *P. Fosbergii* is a member of the section *Pandanus,* but the structure of the apex of the phalange is bizarre for that section, and at a glance more closely resembles the section *Vinsonia.* This is due to the broad and obtuse apex of the phalange which is not lobed. The intercarpellary apical sinuses are superficial and are mere tessellate lines, though in postmaturity wide cracks appear at or near the sinus lines. Diagnostic of the section *Vinsonia* are the flush, horizontal stigmas. In *P. Fosbergii* the stigmas are of another sort. They are large (4–5 mm. long), strongly elevated, oblique and centripetal. Hence, under the present classification of the genus, the new species must be placed in the section *Pandanus.*

Though not a close relative, the most similar appearing species is *P. spiralis* R. Br. of Australia. This species has the phalanges 6 cm. long, the apex convex; carpels 9–20; stigmas 2–3 mm. long, hippocrepiform; seeds 4 mm. in diameter, very narrowly elliptic; and the apical mesocarp of separate caverns. *P. Fosbergii* has the phalanges 8.7 cm. long, the apex low convex; carpels 6; stigmas 4–5 mm. long, suborbicular; seeds 10 mm. in diameter, obovoid; and the apical mesocarp of confluent caverns.

This new species is named for its collector, Dr. F. Raymond Fosberg, of the U. S. Geological Survey.

This species seems to be the one recorded (and doubtless misdetermined) by J. C. Willis and J. S. Gardiner (1901: 104) as *P. Leram* Jones *ex* Fontana. That is a native of the distant Nicobar and Andaman Islands. It has massive phalanges roughly similar to those of the species here described, but the carpels are arranged in transverse, parallel lines, the stigmas are laterally directed, and the species belongs to a different section of the genus, *Hombronia*. They observed the plant, "a very large green stemmed *Pandanus* . . . reaching a height of over 50 feet, found in the Hulule, Turadu, Goifurfehendu, Limbo Kandu, &c. (Gardiner), and known as Karikeo (Keeva in Addu Atoll); . . ."

The tentative record of *P. Hornei* Balf. *f.* in Baker, by Willis and Gardiner (1901: 104), also seems to belong here.

Pandanus Hartmanii sp. nov. (sect. *Pandanus*)
Fig. 15

DIAGNOSIS HOLOTYPI: Arbor 5–6 m. alta circa 12 cm. diametro, ramis horizontalibus deinde adscendentibus griseis laevibus, radicibus fulturosis multis sublaevibus 1–2 m. longis circa 4 cm. diametro et frequenter in 6–10 dm. ex terra divisis in radicellis pluribus, foliis 120 cm. longis 5.7 cm. latis firme subcoriaceis ligulatis in sectio late M-formatis longe attenuatis et in 10 cm. ex apice 2.5 mm. latis proxima basi marginibus cum spinis 3.5–5 mm. longis 8–18 mm. distantibus crassiter subulatis in 45° adscendentibus, midnervio cum spinis reflexis 2–3 mm. longis 10–12 mm. distantibus crassiter subulatis, in sectio mediali marginibus cum spinis 3.5–4.5 mm. longis 5–15 mm. distantibus adpressis crassiter subulatis, midnervio infra cum spinis 2–3 mm. longis 13–23 mm. distantibus adpressis et plerumque adscendentibus, proxima apice marginibus et midnervio infra cum spinis 0.6–0.8 mm. longis 7–14 mm. distantibus, aculeis omnibus cum apicibus nigris, syncarpio solitario terminali scilicet (ex photo) late ellipsoideo et 20 cm. long, 14 cm. diametro, phalangibus 4–4.3 cm. longis 3.2–4 cm. latis 2.8–3.1 cm. crassis in sicco pallide brunneis infra subluteis, lateribus planis vel cum sulcis vadosis paucis 4–6-angulosis, parte supera ⅛ libera, apice convexo, suturis lateralibus nullis, sinibus centralibus apicalibus 3–5 mm. profundis angustis, carpellis 12–14, plerumque 12, apicibus conicis sed valde oblatis et eis centralibus gradatim minoribus interioribus plerumque ½–⅔ tam grandis quam exterioribus, stigmatibus grandis prominentibusque centralibus elevatis sed subhorizontalibus interioribus 3–4 mm. longis 2–2.5 mm. latis ellipticis exterioribus 2–3 mm. longis 3–4 mm. latis irregulariter cordatis, endocarpio centrali 1.7–2 cm. longo osseoso brunneo lateribus 1–3 mm. crassis, seminibus 11–14 mm. longis 4 mm. diametro late ellipsoideis, mesocarpio apicali in quaque carpella cavernoso cum membranis albis medullosis paucis, mesocarpio basali fibroso et carnoso.

DIAGNOSIS OF HOLOTYPE: Tree 5–6 m. tall, about 12 cm. in diameter; branches horizontal, then ascending; trunk gray, smooth; prop roots 1–2 m. long, about 4 cm. in diameter, smooth, many of them at 6–10 dm. from ground dividing into a cluster of smaller rootlets; leaves 1.2 m. long, 5.7 cm. wide, firm subcoriaceous, ligulate, broad M-shaped in section, long attenuate and at 10 cm. from the tip only 2.5 mm. wide, near the base the margins with very stout subulate teeth 3.5–5 mm. long, 8–18 mm. apart, ascending at 45°, the midrib below with mostly reflexed prickles 2–3 mm. long, 10–25 mm. apart, stout subulate; at the midsection the marginal teeth 3.5–4.5 mm. long, 5–15 mm. apart, appressed, stout subulate and heavy-based; the midrib below with prickles 2–3 mm. long, 13–23 mm. apart, appressed, mostly ascending; near the apex the margins and midrib below with prickles 0.6–0.8 mm. long, 7–14 mm. apart; all prickles with darkish tips; syncarp solitary, terminal, apparently broad ellipsoid and 20 cm. long, 14 cm. in diameter; phalanges 4–4.3 cm. long, 3.2–4 cm. wide, 2.8–3.1 cm. thick, quadrate-cuneate, apex convex, upper ⅛ free, sides smooth, shining, light brown, 4–6-angled, the sides flat or with a few shallow furrows, the lower half when dry still yellowish; central apical sinuses 3–5 mm. deep; carpels 12–14, mostly 12; carpel apices conic but the apex much depressed, those towards the center gradually smaller, the central ones ½–⅔ as large as the outer ones; stigmas centripetal, large and

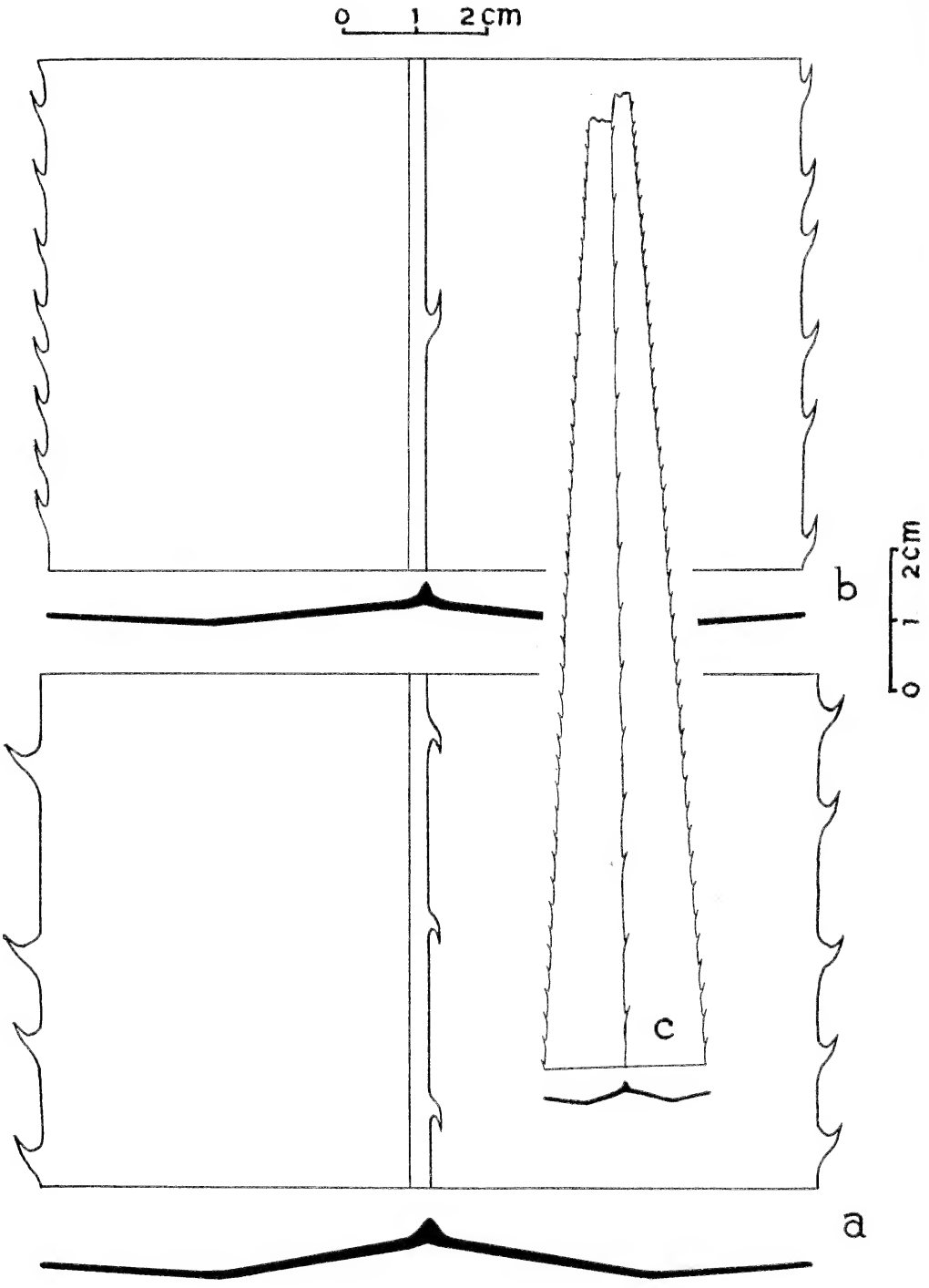

FIG. 14. *Pandanus Fosbergii,* from holotype. *a,* Leaf base, lower side, × 1; *b,* leaf middle, lower side, × 1; *c,* leaf tip, lower side, × 1.

prominent, the inner ones 3–4 mm. long, 2–2.5 mm. wide, elliptic, the outer ones 2–3 mm. long, 3–4 mm. wide, irregularly cordate, elevated, but more or less horizontal; endocarp central, 1.7–2 cm. long, bony, brown, the lateral walls 1–3 mm. thick; seeds 12–13 mm. long, broad ellipsoid; apical mesocarp with ellipsoid caverns mostly empty but with a few transverse white membranes; basal mesocarp fibrous.

HOLOTYPUS: Maldive Islands, Haddumati Atoll, Hitadu Islet, common near shore, Oct. 10, 1957, *W. D. Hartman 3* (Arn., Arb.).

DISCUSSION: *P. Hartmanii* is a member of the section *Pandanus*. The closest relative seems to be *P. tectorius* Soland. var. *spiralis* (Blanco) Martelli, of the Philippines. It has the carpels 6–9, and their apices low pyramidal-convex; and the leaves 5 cm. wide. *P. Hartmanii* has the carpels 12–14, and their apices conic but the apex much depressed; and the leaves 5.7 cm. wide.

This species is named for the anthropologist Dr. W. D. Hartman, member of the recent Yale University Expedition to the Indian Ocean. He collected all but one of the species of *Pandanus* known on the Seychelles Islands, and he collected excellent material of three new species on the Maldive Islands. His notes indicate the presence of others there which were either not in fruit or the fruits of which were not attainable. Because of his excellent collections of these difficult plants it is a pleasure to name this species for him.

Pandanus Karikayo sp. nov. (sect. *Pandanus*) Figs. 16–17

NOM. VERN. "karikayo."

DIAGNOSIS HOLOTYPI: Arbor 4–5 m. alta scilicet 15 cm. diametro, corona ovoidea, cortice sublaevi, radicibus fulturosis evidentibus, foliis 100–125 (–300?) cm. longis 5.2 cm. latis ligulatis subcoriaceis longe attenuatis ad basem V-formatis sed ultra planis in regione basali marginibus cum aculeis 0.5–1 mm. longis 3–5 mm. distantibus salientibus, in regione 15 cm. ex basi cum aculeis 5–7 mm. longis 13–26 mm. distantibus subulatis in 45° adscendentibus, midnervio infra cum aculeis 4–4.5 mm. longis 15–30 mm. distantibus crassiter subulatis recurvatis, in sectio mediale marginibus cum aculeis 5–7 mm. longis 13–26 mm. distantibus adscendentibus, midnervio cum aculeis infra 3.5–4 mm. longis 15–30 mm. distantibus recurvatis, circa apice marginibus midnervioque cum aculeis 0.6–1 mm. longis 3–8 mm. distantibus crassiter subulatis adpresse adscendentibus, aculeis paene totis pallidis, syncarpio unico terminali scilicet 18 cm. longis et 13 cm. diametro rubro late ellipsoideo, phalangibus multis 3.8–4.4 cm. longis 2.1–3.4 cm. latis 2–2.6 cm. crassis obovoideo-cuneatis apice subconvexo parte ¼ supera libera lateribus laevibus lucidis in sicco pallide brunneis curvatis vel minime sulcatis 4–5-angulosis, suturis lateralibus nullis, sinibus apicalibus centralibus 4–8 mm. profundis omnibus angustis vel paucis cum fundam latam, carpellis 10–14 et rare cum carpella laterali abortiva, apicibus conicis adscendentibus depresse subrotundatis omnibus aequalibus vel centralibus minoribus ⅔ tam grandibus quam marginalibus eis saepe conicis asymmetricalibus et clare divengentibus, stigmatibus 1.5–2.5 mm. longis ellipsoideis obliquis elevatis prominentibus centripetalibus breve sulcatis, sutura proximali ⅓ distancia ad fundam extenta, endocarpio centrali osseoso mahogani-colorato marginibus lateralibus 1.5–2 mm. crassis, seminibus 10–11 mm. longis ellipsoideis, mesocarpio apicali in quaque carpella cavernoso fibroso et cum membranis subalbis medullosis, mesocarpio basali cum fibris fortibus.

DIAGNOSIS OF HOLOTYPE: Trees 4–5 m. tall, about 15 cm. in diameter; trunk rather smooth; crown ovoid; prop roots diverging at about 40°; leaves 100–125 (–300?) cm. long, 5.2 cm. wide, subcoriaceous, ligulate, long attenuate, towards the base V-shaped, beyond it plane, near the base the margins with salient prickles 0.5–1 mm. long, 3–5 mm. apart, but at 15 cm. up from the base the prickles 5–7 mm. long, 13–26 mm. apart, subulate, ascending at 45°, the nearby midrib below with prickles 4–4.5 mm. long, 15–30 mm. apart, stout subulate, recurving; at the middle the margins with prickles similar to those near the base but ascending at 25°–40°, the midrib below with prickles 4–4.5 mm. long, 15–30 mm. apart, stout subulate, recurving; near the apex the margins and midrib below with prickles 0.6–1 mm. long, 3–8

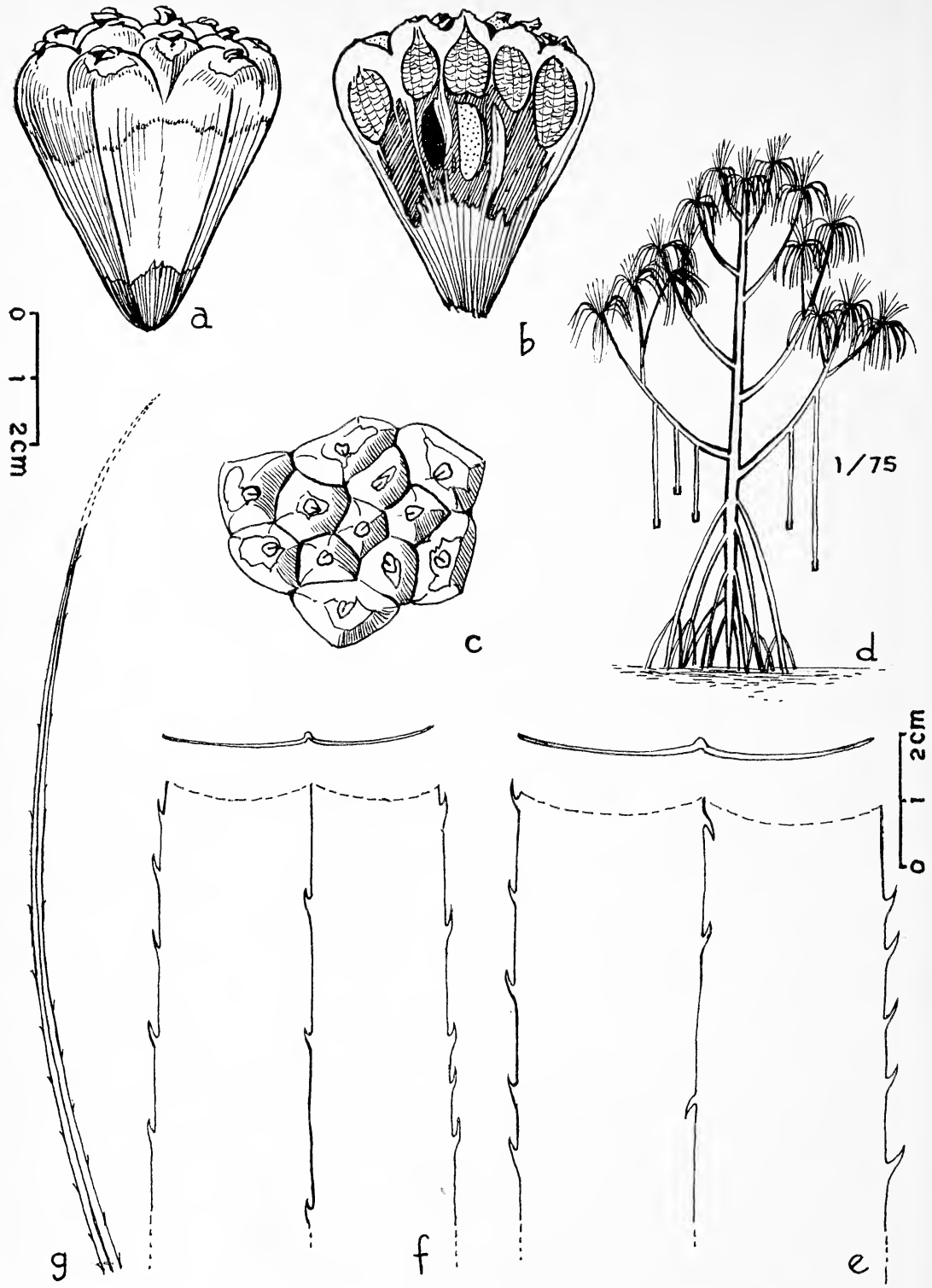

FIG. 15. *Pandanus Hartmanii,* from holotype. *a,* Phalange, lateral view, × 1; *b,* phalange, longitudinal section, × 1; *c,* phalange, apical view, × 1; *d,* tree, × 1/75; *e,* leaf base, lower side, × 1; *f,* leaf middle, lower side, × 1; *g,* leaf tip, lower side, × 1.

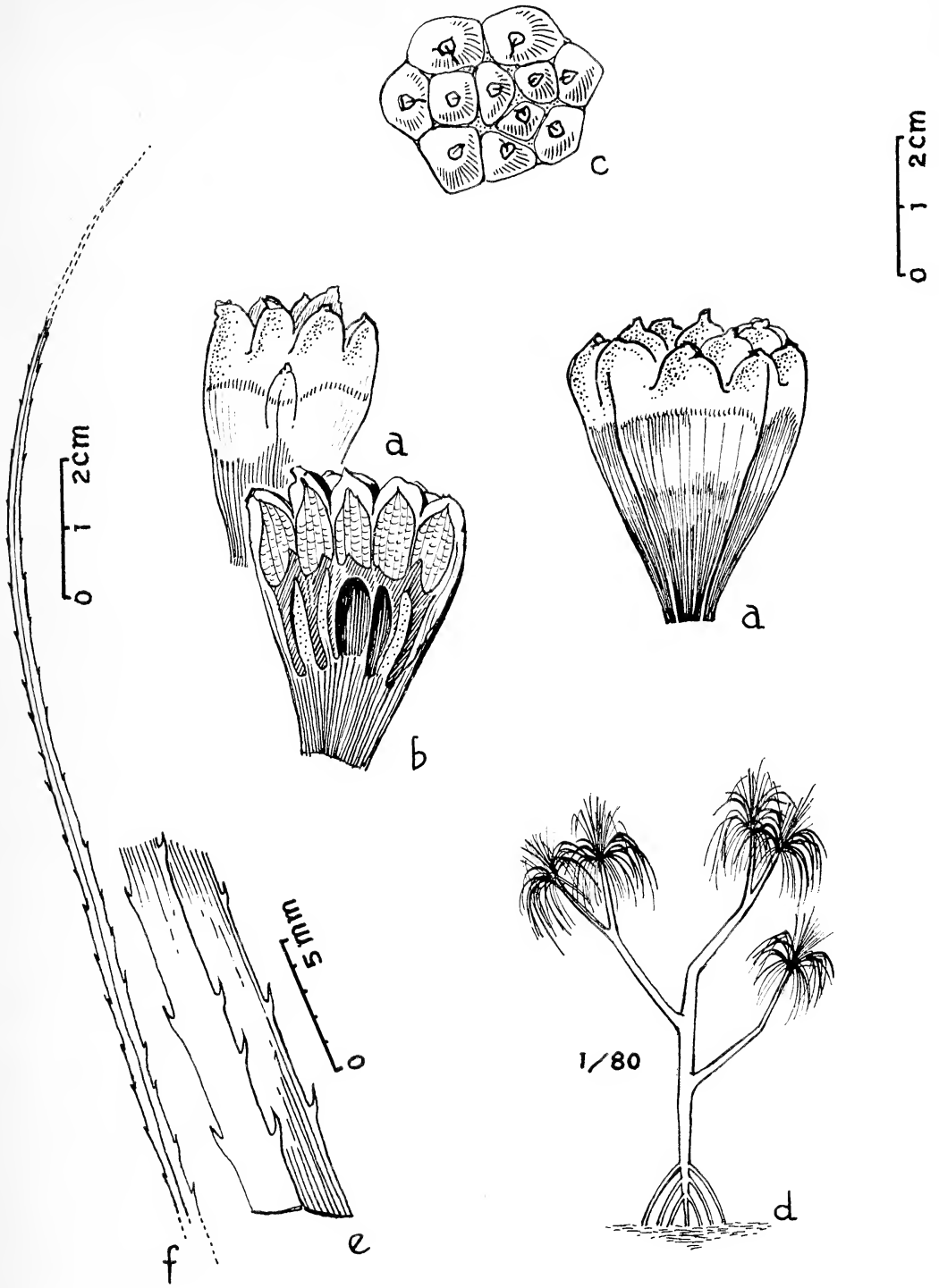

FIG. 16. *Pandanus Karikayo*, from holotype. *a*. Phalanges, lateral view, × 1; *b*, phalange, longitudinal section, × 1; *c*, phalange, apical view, × 1; *d*, tree, × 1/80; *e*. leaf apex, lower side, × 4; *f*, leaf apex, upper side, × 1.

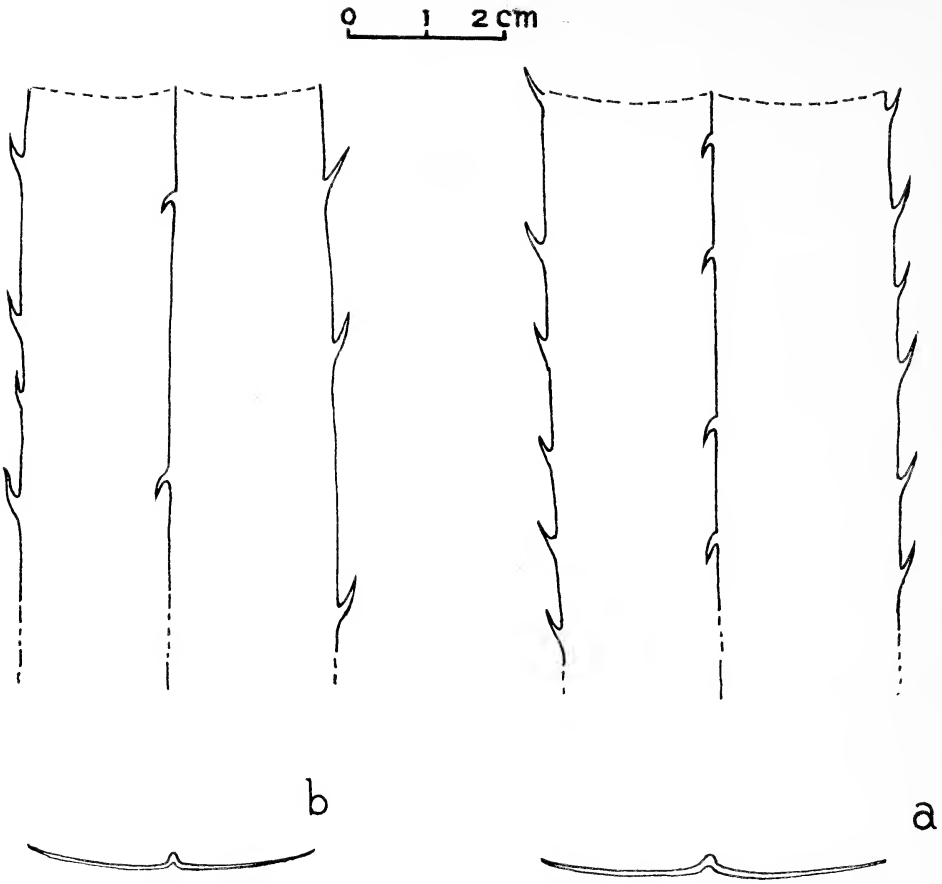

FIG. 17. *Pandanus Karikayo,* from holotype. *a,* Leaf base, lower side, × 1; *b,* leaf middle, lower side, × 1.

mm. apart, stout subulate, closely ascending; prickles all pale; syncarp single, terminal, broad ellipsoid, apparently 18 cm. long, 13 cm. in diameter, "bright red"; phalanges numerous, 3.8–4.4 cm. long, 2.1–3.4 cm. wide, 2–2.6 cm. thick, obovoid-cuneate, apex slightly convex, upper ¼ free, sides smooth, shining, when dry light brown, curving or slightly channeled, 4–5-angled; lateral sutures none; apical central sinuses 4–8 mm. deep, all narrow or a few broad based; carpels 10–14, rarely with a tiny, lateral, splintlike one also; carpel apices ascending, depressed, somewhat rounded conic, but the marginal ones often conic, asymmetric and distinctly divergent, all subequal or the ones toward the center somewhat smaller, these about ⅔ as large as the marginal ones; stigmas 1.5–2.5 mm. long, ellipsoid, short creased, prominent, raised, oblique, centripetal; proximal suture extending ⅓ way to the valley bottom; endocarp central, bony, mahogany-colored, the lateral margins 1.5–2 mm. thick; seeds 10–11 mm. long, ellipsoid; apical mesocarp in each carpel forming a large cavern with strong longitudinal fibers and whitish pithy partitions; basal mesocarp with strong fibers.

HOLOTYPUS: Maldive Islands, Fadiffolu Atoll, Kuredu Islet, common on shore and middle, Sept. 25, 1957, *W. D. Hartman 1* (Arn. Arb.).

DISCUSSION: *P. Karikayo* is a member of the section *Pandanus*. Its closest relative appears to be *P. odoratissimus* L. *f.*, of the island of Ceylon, which has the phalanges with the upper ⅓ free; the central apical sinuses 4 mm. deep; and the stigmas of the outer carpels horizontal. In *P. Karikayo* the phalanges have the upper ¼

free; the central apical sinuses 4–8 mm. deep; and the stigmas of the outer carpels divergent.

The new specific epithet is the vernacular name of the species on Fadiffolu Atoll.

Pandanus maldivecus sp. nov. (sect. *Pandanus*) Fig. 18

NOM. VERN.: "karikayo."

DIAGNOSIS HOLOTYPI: Arbor 2–6 m. alta, trunco scilicet 12 cm. diametro cum foliis subpersistentibus, radicibus fulturosis scilicet 3–6 dm. longis et laevibus, foliis 117 cm. longis 4 cm. latis ligulatis subcoriaceis longiter attenuatis in sectio ad basem W-formatis ad mediam planatis, apice longe acuminato et in 10 cm. ex apice 2.5 mm. lato, ad basem marginibus cum aculeis 2–4.5 mm. longis 9–22 mm. distantibus crassiter subulatis adscendentibus, midnervio ad basem infra cum aculeis 2–3 mm. longis 1–3 cm. distantibus subulatis valde reflexis, in regione mediali marginibus cum aculeis 1.5–2.5 mm. longis 8–17 mm. distantibus, midnervio infra cum aculeis 1.5–2 mm. longis 15–22 mm. distantibus subulatis adscendentibus, proxima apice marginibus cum dentibus 0.3–0.5 mm. longis 3–7 mm. distantibus, aculeis omnibus cum apice nigro, syncarpio solitario terminali 14 cm. longo 11 cm. diametro late ellipsoideo cum circa 60 phalangibus eis 4.8–5.2 cm. longis 2.5–3.4 cm. latis 2.2–2.9 cm. crassis obovoideis cuneatis scilicet luteis in sicco pallide brunneis laevibus lucidis lateribus planatis vel rare vadoso-sulcatis 4–6-angulosis parte ¼ supera libera, apice convexo sinibus apicalibus centralibus 2–3 mm. profundis angustis vel latis, carpellis 5–9 plerumque 6, apicibus valde depresso-pyramidalibus eis marginalibus clariter cum apice et stigmate divergenti, apicibus interioribus minoribus, centralibus ⅔ tam grandis quam marginalibus, stigmatibus 2.5–3.5 mm. longis ovatis vel rhombicis prominentibus elevatis centripetalibus, sutura proximali ¼ distancia ad fundum extenta, endocarpio paene submediali osseoso obscure mahogani-colorato marginibus lateralibus 1.5–2 mm. crassis, seminibus 11–13 mm. longis 4 mm. diametro asymmetriciter ellipsoideis, mesocarpio apicali cum cavernis cum membranis firmis albis completis, mesocarpio basali fibroso et carnoso.

DESCRIPTION OF ALL SPECIMENS EXAMINED: Tree 2–6 m. tall, and about 12 cm. in diameter, the bark and roots appearing smooth; trunk usually more or less clothed with persistent, dead leaves; leaves 117 cm. long, 4–5 cm. wide, ligulate, subcoriaceous, towards the base W-shaped, further out plane, then long attenuate, the apex 10 cm. back only 2.5 mm. wide; near the base the margins with prickles 2–4.5 mm. long, 9–22 mm. apart, stout subulate, ascending; the midrib the only prominent nerve, and near the base with prickles below 2–3 mm. long, 1–3 cm. apart, strong subulate, reflexed; near the middle the margins with prickles 1.5–2.5 mm. long, 8–17 mm. apart; the midnerve below with prickles 1.5–2 mm. long, 15–22 mm. apart, reflexed; near the tip the margins and midrib below with prickles 0.3–0.5 mm. long, 3–7 mm. apart; all the prickles dark-tipped; syncarp solitary, terminal, 14 cm. long, 11 cm. in diameter, broad ellipsoid, with about 60 phalanges, these 4.8–5.2 cm. long, 2.5–3.4 cm. wide, 2.2–2.9 cm. thick, obovoid, cuneate, apparently yellow, when dry pale brown, shining, the sides smooth, shining, plane or a few of them shallow furrowed, 4–6-angled, upper ¼ free, the apex convex; central apical sinuses 2–3 mm. deep, narrow or broad; carpels 5–9, mostly 6; carpel apices much depressed pyramidal, the marginal ones with apex and stigmas distinctly diverging, the others decreasing in size towards the center, the central ones being about ⅔ size of the marginal ones; stigmas 2.5–3.5 mm. long, ovate to rhombic, short creased, prominent, raised, centripetal; the proximal suture running ¼ way to valley bottom; endocarp slightly submedian, bony, dark mahogany-colored, the lateral margins 1.5–2 mm. thick; seeds 11–13 mm. long, 4 mm. in diameter, asymmetric ellipsoid; apical mesocarp with a cavern in each carpel, these filled with white, firm, cross membranes; basal mesocarp fibrous and fleshy.

HOLOTYPUS: Maldive Islands, South Malosmadulu Atoll, Dunikolu Islet, common, chiefly on the shore, Oct. 2, 1957, *W. D. Hartman 2* (Arn. Arb.).

SPECIMENS EXAMINED: Maldive Islands, Malé Atoll, Malé Islet, forming thicket back of seaward beach, 1–2 m. alt., nom. vern "bokio," fruits red on ripening, not eaten or used for

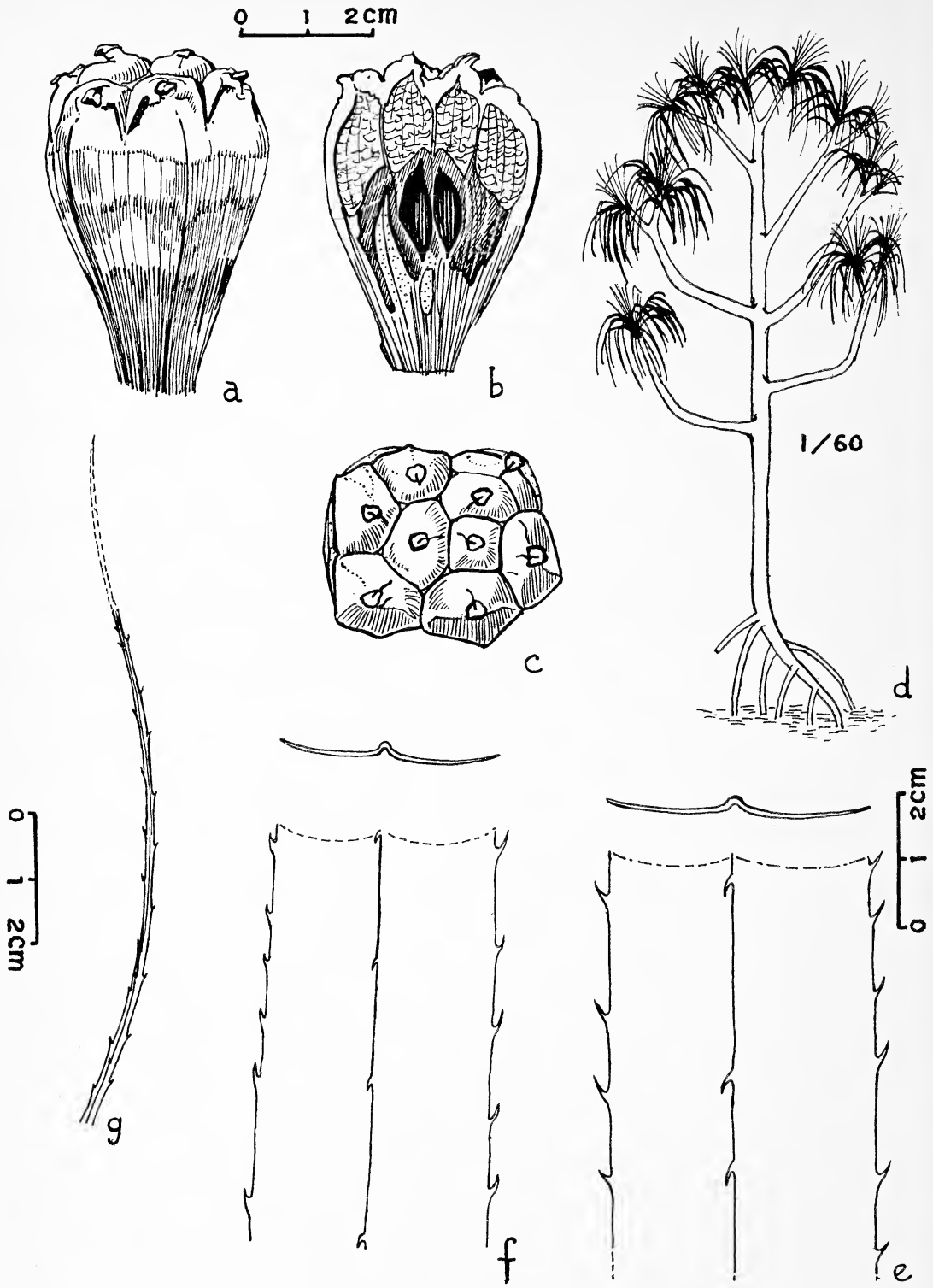

FIG. 18. *Pandanus maldivecus,* from holotype. *a,* Phalange, lateral view, × 1; *b,* phalange, longitudinal section, × 1; *c,* phalange, apical view, × 1; *d,* tree, × 1/60; *e,* leaf base, lower side, × 1; *f,* leaf middle, lower side, × 1; *g,* leaf apex, lower side, × 1.

anything, April 12, 1956, *F. R. Fosberg 36,916* (US).

DISCUSSION: *P. maldivecus* is a member of the section *Pandanus*. Its closest relative seems to be *P. tectorius* Sol. var. *sarawakensis* Martelli of Borneo. This has the phalanges 6–6.5 cm. long, the upper ½ free, the sides flat or more or less concave; central apical sinuses apparently 4–5 mm. deep; and the stigmas 2–2.8 mm. long, inflexed even on the marginal carpels. In contrast, *P. maldivecus* has the phalanges 4.8–5.2 cm. long, upper ¼ free, the sides plane and curved or shallowly furrowed; central apical sinuses 2–3 mm. deep; and the stigmas of the marginal carpels distinctly diverging.

The new specific epithet is taken from the geographic name Maldive, to which is added a Latin adjectival suffix.

Pandanus OF THE SEYCHELLES ISLANDS

Pandanus Balfourii Martelli, Webbia 1: 361–362, 1905; 4(1): 7, t. 4, figs. 4–7, 1913 (sect. *Pandanus*)
Fig. 19

This species was briefly described, then later illustrated by Martelli, from collections from the Seychelles made by Horne and by Dupont. It is a well-marked species, and its status is not in question. However, the collection, data, and photos by Dr. W. D. Hartman, made in 1957, make possible an expanded and more complete description, including stems, leaves, etc. The supplementary descriptive details are as follows:

Tree 5–6 m. tall, and at a point just above the roots 15–17.5 cm. in diameter, but below the first branches 20–23 cm. in diameter, appearing smooth; crown semiorbicular; prop roots borne up to 6 dm. from the ground; leaves 125–145 cm. long, 4.6–4.8 cm. wide, firm, strong, subcoriaceous, ligulate, M-shaped in cross-section, the tip long, slender acuminate to a subulate tip, this at 10 cm. down only 2 mm. wide, at 20 cm. only 8 mm. wide, near the base the margins with prickles 3–3.5 mm. long, 3–10 mm. apart, stout, broad-based subulate, salient ascending, the nearby midrib below beginning 12 cm. up with prickles 2.5–3 mm. long, 10–25 mm. apart, stout subulate, reflexed; at the midsection the margins with prickles 2–2.5 mm. long, 2–5 mm. apart, appressed ascending and more slenderly subulate, tipped with dark brown; the midrib below with prickles 1.5–2 mm. long, 7–15 mm. apart, slender subulate, ascending-subappressed; near the apex the margins and midrib below with prickles 0.3–0.5 mm. long, 2–3 mm. apart, stout subulate, broad based, appressed–ascending, brown tipped; phalanges 102; these 3.7–4 cm. long, 2–4.3 cm. wide, 1.6–2.5 cm. thick, upper 1/5–¼ free, apex low convex, sides gently convex or plane, shining, pale brown when dry; lateral sinuses none; lateral furrows none or slight, 4–6-angled, lower half fibrous and fleshy and orange; central apical sinuses 1–2 mm. deep, shallow, broad V-shaped; carpels 5–10, their apices low, rounded pyramidal, green when ripe; stigmas 1–2 mm. long, suborbicular to cordate; endocarp dark brown, slightly supramedian, the lateral margins 1–2 mm. thick.

SEYCHELLES ISLANDS: Mahé Island, opposite Souris Island, group on granite cliffs near shore, Nov. 9, 1957, *W. D. Hartman 6* (Arn. Arb.).

Pandanus Hornei Balf. *f.*, in Baker, Fl. Mauritius and Seychelles 397, 1877; Martelli, Webbia 4(1): 17, t. 16, figs. 1–3, 1913 (sect. *Dauphinensia*), new sectional placement
Figs. 20–21

NOM. VERN.: "vacoa parasol."

This very distinct species has been known for nearly a century. The phalanges were later illustrated by Martelli, but his figures did not clarify the remarkable stigmatic apparatus. Now, the recent collection and data by Dr. W. D. Hartman allow the furnishing of a supplementary description and more adequate illustrations, as follows:

Trees 15–20 m. tall, and the trunk at 3 m. from the ground 15–17.5 cm. in diameter, at 7–10 m. up 20–22.5 cm. in diameter, tall straight, twice trichotomous, then dichotomous; prop roots 2.4–3 m. long, nearly vertical and seeming to hug the trunk; leaf (1 seen) 2.25 m. long, 10 cm. wide, subcoriaceous, gradually tapering to the elongate apex (but the tip lost), at base 1-furrowed, further out M-plicate, at base the margin entire for 11 cm., then in-

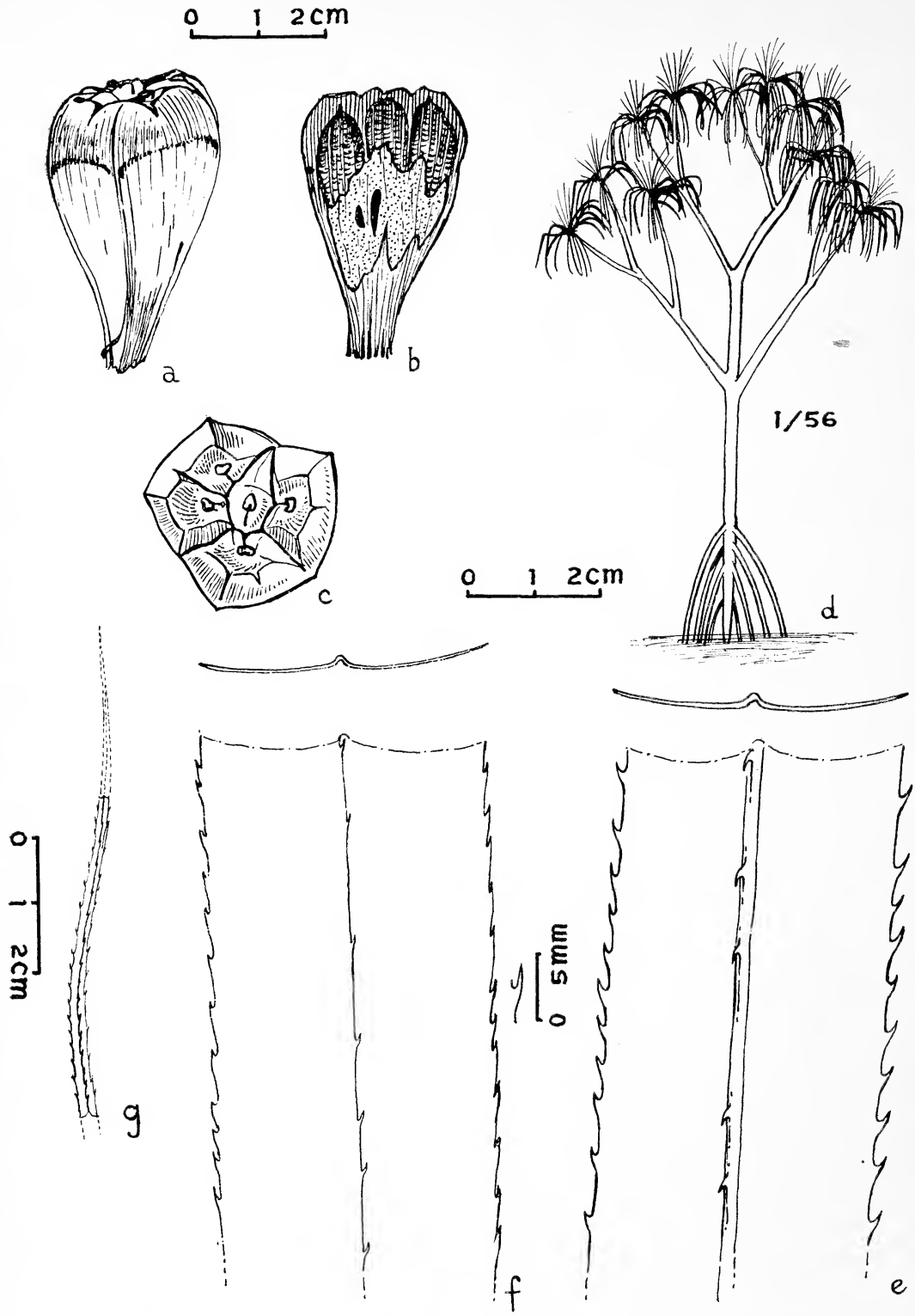

FIG. 19. *Pandanus Balfourii,* from Mahé I., *Hartman 6. a,* Phalange, lateral view, × 1; *b,* phalange, longitudinal section, × 1; *c,* phalange, apical view, × 1; *d,* tree, × 1/56; *e,* leaf base, lower side, × 1; *f,* leaf middle, lower side, × 1, and one prickle × 2; *g,* leaf apex, lower side, × 1.

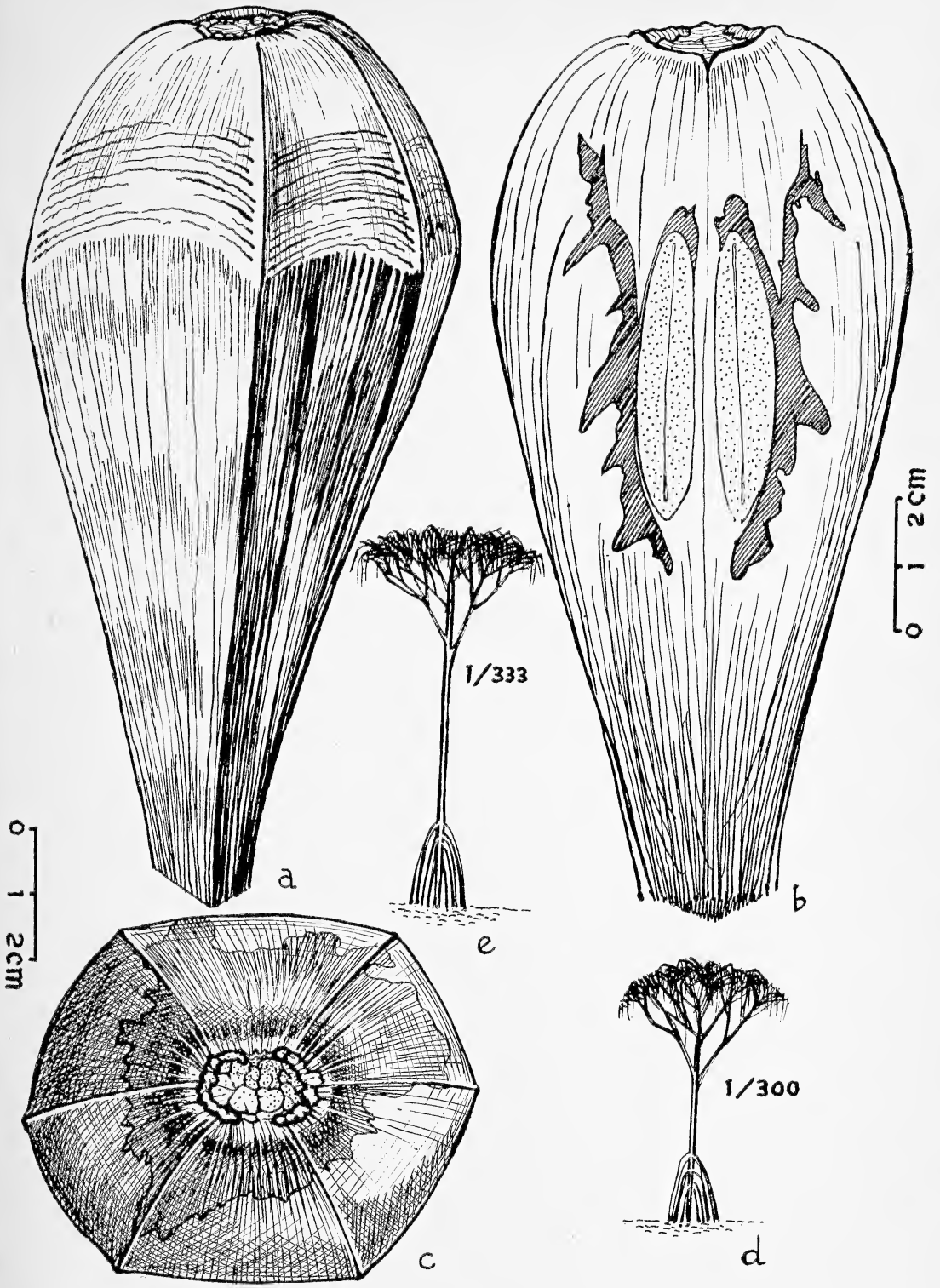

FIG. 20. *Pandanus Hornei,* from Praslin I., *Hartman* 7. *a,* Phalange, lateral view, × 1; *b,* phalange, longitudinal section, × 1; *c,* phalange, apical view, × 1; *d,* medium-size tree, × 1/300; *e,* large tree, × 1/333.

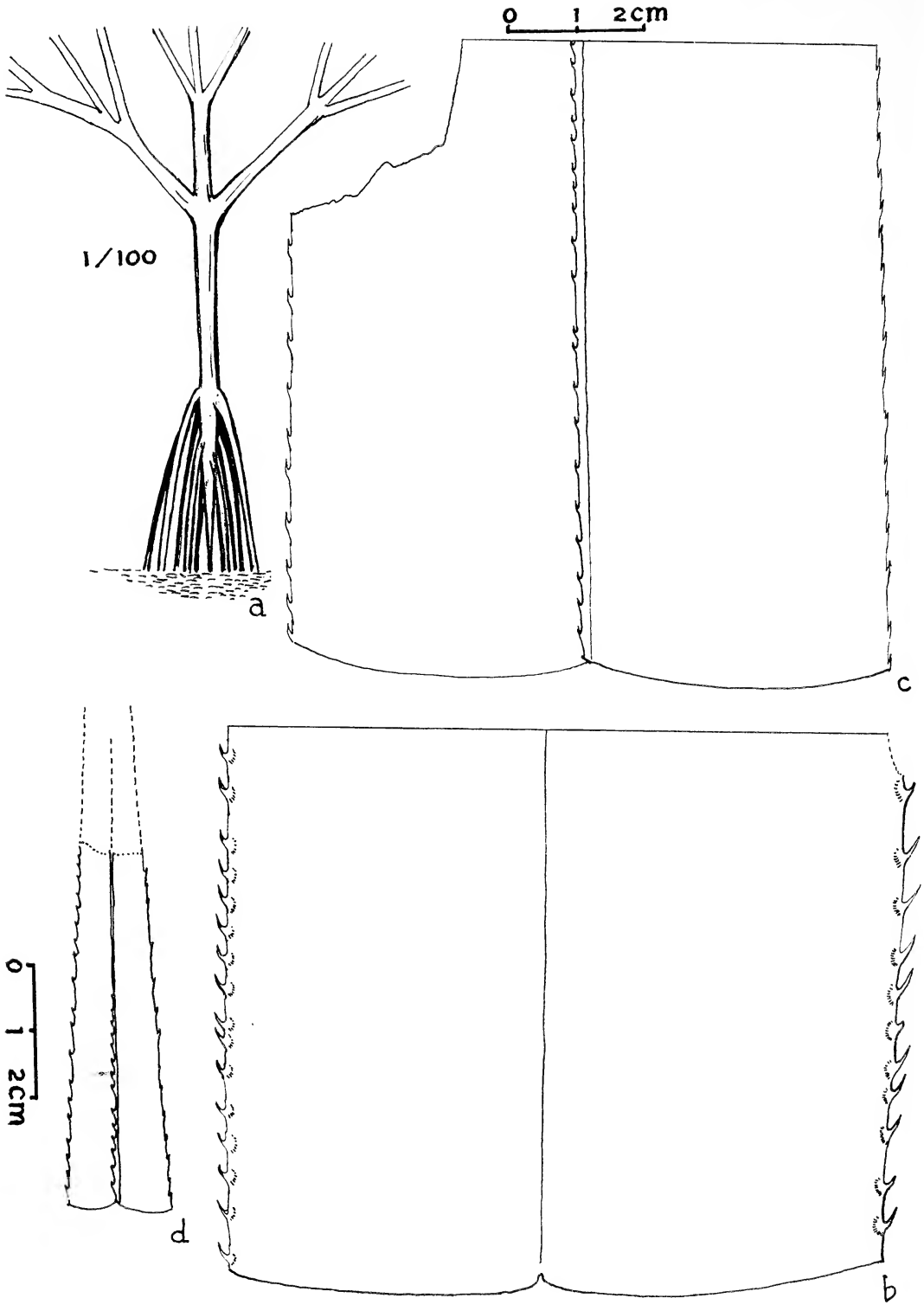

FIG. 21. *Pandanus Hornei,* from Praslin I., *Hartman* 7. *a,* Trunk, branches, and prop roots, × 1/100; *b,* leaf base, lower side, × 1; *c,* leaf middle, lower side, × 1; *d,* leaf apex, lower side, × 1.

creasingly coarsely aculeate, the prickles 3–4.5 mm. long, 3–10 mm. apart, stout subulate, upward curved, blackish; the nearby midrib unarmed; at midsection the marginal prickles 2 mm. long, 3–5 mm. apart, dark brown, subulate, upward curved; the midrib below with prickles 1 mm. long, 4–6 mm. apart, subulate, appressed ascending; near the tip the margins and midrib below with aculeate-serrations 0.2–0.4 mm. long, 1–2 mm. apart, brown, appressed ascending; pistillate inflorescences single, terminal; phalanges (4 seen) 12.2–13.2 cm. long, 5.3–6.8 cm. wide, 5–6.3 cm. thick, cuneate oblanceoloid, the apex rounded, upper ¼ free and green, glaucous, the lower ¾ fleshy, reddish orange, the sides smooth, above slightly convex, below plane; apex with a central rounded rim and within a concavity 2 mm. deep, the surface of which is covered by several irregular, unequal, cordate elevations which at first glance would seem to be stigmas, but are not these; and in some there is an apical central crack 1 mm. deep; along the apical rim are two arcuate or parenthesis-like, wavy ridges which are the two centripetal stigmas which along the perimeter are 20–22 mm. long; indocarp in upper 2/5, bony, dark brown, the lateral margins at the thinnest parts 3–4 mm. thick; seeds 45–46 mm. long, 10–11 mm. in diameter; mesocarp continuous, of solid pith and few longitudinal fibers.

SEYCHELLES ISLANDS: Praslin Island, Vallée de Mai, near stream, 500–600 ft. elev., Nov. 11, 1957, *W. D. Hartman 7*.

He also recorded, "Another stand of these trees was later seen (and photographed) growing along a stream near Newcombe Forest, Praslin Island. They were not quite as tall as the trees in the Vallée de Mai."

DISCUSSION: The crowded, cordate elevations in the apical concavity of the phalange are deceptively like stigmas. Only after careful study of the apex and of cut sections was it demonstrated that the actual stigmas were the two arcuate or parenthesis-like projections on the central apical rim. It would have been a pleasure to publish Hartman's excellent color photos of this species, but the cost forbids.

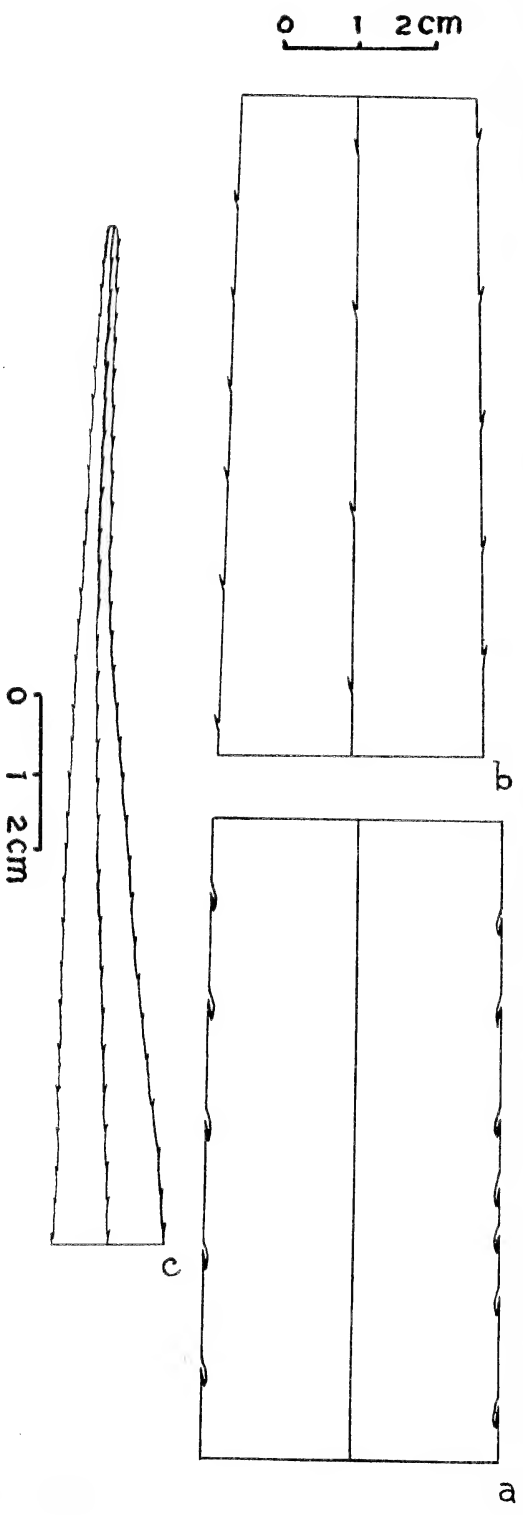

FIG. 22. *Pandanus sechellarum*, from Mahé I., *Hartman 5*. *a*, Leaf base, lower side, × 1; *b*, leaf middle, lower side, × 1; *c*, leaf apex, lower side, × 1.

Pandanus multispicatus Balf. *f.*, in Baker, Fl. Mauritius and Seychelles 403, 1877; Warburg, Engler's Pflanzenreich IV, 9: 67–68, 1900; Martelli, Webbia 4(1): 24, 1913 (sect. *Microstigma*)

SEYCHELLES ISLANDS: endemic.

Martelli's record of this species for Reunion Island was not confirmed by Vaughan and Wiehe (1953: 31). This species has never been illustrated.

Pandanus sechellarum Balf. *f.*, in Baker, Fl. Mauritius and Seychelles 402, 1877; Martelli, Webbia 4(1): 30, t. 7, figs. 6–8, 1913 Fig. 22

NOM. VERN.: "vacoa marron."

This was collected by Hartman in 1957, but since he found only half-grown fruits, his collection furnished only vegetative characters to supplement the known ones, as follows:

Prop roots present up to 6 dm. from ground; leaves 88–90 cm. long, 4–4.2 cm. wide, subcoriaceous, dark green above, paler below, ligulate, tapering gradually to the acute apex, this at the point 10 cm. down 11 mm. wide, M-shaped in section, the enlarged base entire, but beginning 10 cm. up the margins with prickles 1.5–2 mm. long, 7–16 mm. apart, acicular, appressed and seeming like a continuation of the margin since located above a concavity; the nearby midrib unarmed; at the midsection the teeth of the margins 1–1.5 mm. long, 11–26 mm. apart, acicular, appressed ascending; the midrib below with prickles 0.5–1 mm. long, 10–20 mm. apart, acicular, appressed ascending; near the tip the margins and midrib below with teeth 0.2 mm. long, 3–6 mm. apart, subulate, broad based, appressed ascending.

SEYCHELLES ISLANDS: Mahé Island, opposite Souris Island, group of 6–8 trees among granite boulders near shore, shaded by coconut palms, Nov. 9, 1957, *W. D. Hartman 5.*

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A Contribution to the Ecology of the Kermadec Islands

V. J. CHAPMAN[1]

IN 1956 and 1957, owing to the kindness of the Civil Aviation Department, to whom especial thanks are due, it was possible for two visits to be made to the Kermadec Islands. These visits were made under the aegis of the Botany Department, Auckland University, though on the first occasion the personnel included members from elsewhere. The first visit took place in May and June, 1956, and the members of the party were Dr. R. C. Cooper (botanist, Auckland Institute and Museum), P. L. Bergquist (Botany Dept.), and J. S. Edwards (Zoology Dept.). This party was originally expected to stay only a fortnight but, owing to circumstances beyond our control, they were there for a month. Transport facilities to the Kermadecs were generously provided by the Royal New Zealand Navy and return transport by the N. Z. Institute of Oceanography, to whom thanks are due. The second visit took place in October, 1957, when only one scientist could be accommodated on the normal supply vessel. The late D. Knowlton went on this occasion, and in the course of the three days available he was able to achieve much valuable work.

The original purpose of these visits was to set up permanent quadrats so that the regeneration of vegetation after the reduction of the goat population could be followed over a course of years. It is therefore hoped that further visits may be made in the future. The first visit in 1956 coincided with the end of a drive to eliminate the goats from the island, when some 1,500 goats were shot. About a hundred more were shot in 1956–57. As a result of these activities the goat population was reduced to the point where it could reasonably be hoped that it might be kept in check. Another purpose of the visits was to study more intensively the algal flora of the Kermadecs. It is true that earlier collections and lists had been made by the Gepps (1911) and by Cotton (1912), but in view of the importance of the Kermadecs in relation to sea temperatures and tropical influences, it was believed that a more intensive study would reveal the existence of more species of tropical affinities. This has indeed proved to be the case. Later, in another communication, it is intended to compare the flora of these islands with those from the North Cape region of New Zealand and Norfolk Island.

So far as the terrestrial flora is concerned, extensive lists were already in existence as a result of visits by Cheeseman in 1887 and by Oliver in 1909 to the islands. These earlier workers had collected methodically and extensively and there were no outstanding additions to be made to the earlier lists. One feature of interest was the way in which the taro, *Alocasia macrorrhiza,* had spread over the island since its introduction some time after 1909.

ALGAE

In the list that follows, algae recorded also by the Gepps (1911) are noted by ***G*** and those also recorded by Cotton by ***C.*** Algae newly added to the New Zealand flora are marked by †. Those not collected in 1956 or 1957 are marked by *.

MYXOPHYCEAE[2]

Chlorococcales

Anacystis thermalis (Menengh.) Dr. & Daily. Supralittoral fringe pool, Lava Pt.

Anacystis montana (Lightf.) Dr. & Daily. On rotten log, Green Lake; supralittoral fringe pool, Lava Pt.

Pleurocapsales

Entophysalis conferta (Kütz.) Dr. & Daily. Fleetwood Bluff, supralittoral fringe: on *Derbesia* 4–8 m. down, Meyer Is.

[1] The University of Auckland, New Zealand. Manuscript received November 7, 1960.

[2] I am grateful to Dr. F. Drouet for determinations of this group.

Nostocales

Lyngbya confervoides C. Ag. Fleetwood Bluff, supralittoral fringe; mid-littoral pool, Meyer I.; on *Pterocladia,* Lava Pt.

Lyngbya semiplena (C. Ag.) J. Ag. Fishing Rock, sheltered supralittoral pool, also Hutchinson's Bluff: on *Pterocladia,* Lava Pt.

Phormidium corium (Ag.) Gom. On *Pterocladia,* Lava Pt.

Phormidium autumnale (Ag.) Gom. Locality unknown.

Hydrocoleum glutinosum (Ag.) Gom. Fleetwood Bluff, sheltered crevice (mid-littoral), also supralittoral fringe.

Hapalosiphon laminosus Hansgirg. On fumarole orifice.

Tolypothrix tenuis Kütz. Supralittoral fringe pool, Lava Pt.

Scytonema hofmani Ag. On rotten log, Green Lake.

Amphithrix violacea (Kütz.) Born. et Flah. Fleetwood Bluff, supralittoral fringe.

Plectonema nostocorum Bornet. Supralittoral fringe pool, Lava Pt.

Calothrix crustacea Thur. Fishing Rock, sheltered supralittoral pool, also on wet concrete.

CHLOROPHYCEAE

Ulotrichales

G *Ulva lactuca* var. *rigida* (Ag.) Le Jol.

G **Ulva laetevirens* Aresch.

† *Enteromorpha kylinii* Bliding. The record of this species gives the alga a great discontinuity. In view of the relatively recent recognition of this species, however, it is likely that a wider distribution will be found for it than at present recorded. Supralittoral fringe, Hutchinson's Bluff, on rocks always wet with spray.

G * *Enteromorpha compressa* Grev.

Enteromorpha prolifera (Muel.) J. Ag. f. *crinata* (Roth.) comb. nov. Young plants which probably belong to this species. Supralittoral fringe, Meyer I.

Chaetophorales

Trentepohlia jolithus Wallr.

Oedogoniales

Oedogonium sp. } Neither fertile,
Bulbochaete sp. } Green Lake.

Siphonocladales

Lola tortuosa (Dillw.) Chapm. Fishing Rock, sheltered supralittoral pool.

Rhizoclonium hookeri Kütz. Fleetwood Bluff, on Pohutakawa log.

Rhizoclonium hieroglyphicum Kütz. emend Stockm. Waterfall near Hutchinson's Bluff; Blue Lake.

G C *Cladophora prolifera* (Roth) Kütz. This is recorded as *C. fusca* Marten by both the Gepps and Cotton. For a discussion on this matter the reader is referred to Chapman (1956). Deep mid-littoral pool, Lava Pt.; sublittoral, Meyer I. to 8 m.

Cladophora fracta (Dillw.) Kütz. var. *lacustris* (Kütz.) Brand ex Heering. Waterfall near Hutchinson's Bluff.

Cladophoropsis herpestica (Mont.) Chapm. Boat Cove, Fishing Rock.

† *Cladophoropsis membranacea* Borg.

† *Cladophoropsis membranacea* Borg. var. *repens* (J. Ag.) Phinney. I believe two plants have been confused here. There is a cushion-like *Cladophora, C. repens,* and there another plant which is clearly a *Cladophoropsis* in that the branches have no cells at the base. Supralittoral pool, Meyer I.

Microdictyon umbilicatum (Velley) Zanard. Only occurs elsewhere in New Zealand on Mayor I. (Chapman, 1956).

Dasycladales

† *Acetabularia parvula* Solms-Laubach. Mid-littoral pool, Fishing Rocks.

Siphonales

Derbesia novae-zelandiae Chapm. This was probably the plant that the Gepps recorded as *Vaucheria* sp. Pool in sublittoral fringe, pool mid-littoral, Fishing Rocks; sublittoral, 4–8 m., Meyer I.

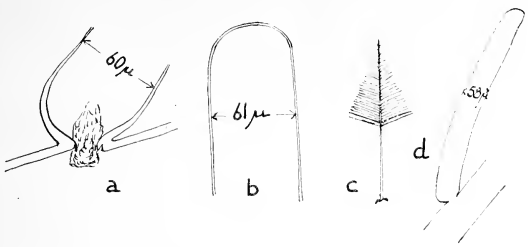

FIG. 1. *Bryopsis kermadecensis. a,* Base of pinnule showing constriction and plug of protoplasm; *b,* apex of pinnule; *c,* plant (× 2); *d,* pinnule.

† *Bryopsis kermadecensis* sp. nov. (Fig. 1). Plantis 1.5 cm. longis, axe primario distincto, simplici, 149–158 μ dia., pariete 6–6.5 μ crasso, partibus inferioribus nudis; pinnulis inferioribus caducis, pinnulis superioribus radialiter dispositis, basi constrictis, apici obtusis, 44–61 μ dia.

Plants 1.5 cm. long, main axis distinct, unbranched, 149–158 μ diam., wall 6–6.5 μ thick, lower part bare below; lower pinnules deciduous, upper pinnules radially arranged, constricted at the base, obtuse at the apex, 44–61 μ diam.

Type specimen in Lind. Herb. Auckl. Univ.

This species is very close to *B. derbesioides* Chapm., but differs in its smaller size and the greatly constricted bases of the branches. The diameter of the pinnules is also more uniform and the apices obtuse rather than tapering. It appears to be smaller than other species of *Bryopsis* recorded from the Australian mainland. For the present, therefore, it has been regarded as a new species, though extensive collecting will be necessary before any further decision can be made. On *Corallina* in sublittoral pool, Fishing Rocks.

G * *Codium dichotomum* (Huds.) S. F. Gray f. *novozelandicum* Dellow. This is the plant recorded by Gepp as *C. tomentosum.* (See Chapman, 1956.)

Codium adhaerens (Cabr.) Ag. var. *convolutum* Dellow. Sublittoral, Onerahi Bluff.

† *Caulerpa racemosa* (Forsk.) J. Ag. var. *peltata* (Lmx.) Eubank, Mid-tide pool, Fishing Rocks.

G *Caulerpa racemosa* (Forsk.) J. Ag. var. *uvifera* (Turn.) J. Ag. f. *intermedia* Web. van Bosse. Fishing Rock, mid-littoral pool: sublittoral, 12 m., and sublittoral fringe, Meyer I.

† *Caulerpa webbiana* Mont. Deep pool, mid-tide, Fishing Rock with *Corallina*; sublittoral, 12 m., Meyer I.

PHAEOPHYCEAE

Dictyotales

G *Dictyota prolificans* A. & E. S. Gepp. In red turf, Hutchinson's Bluff, mid-littoral.

C G *Taonia australasica* (Kütz.) J. Ag. Sublittoral, 4–8 m., Meyer I.

C G *Pocockiella nigrescens* (Sond.) Papenf. Pool, Boat Cove: in *Corallina* turf, sublittoral, Fishing Rocks.

Padina fraseri (Grev.) J. Ag. (Lindauer, 1957).

Hydroclathrus clathratus (Bory) Howe (Lindauer, 1957).

C * *Haliseris kermadecensis* Cotton

Sporochnales

C * *Perithalia capillaris* J. Ag.

Dictysiphonales

Colpomenia sinuosa (Roth.) Derb. et Sol. Fishing Rocks.

Fucales

C * *Sargassum sinclairii* Hook. f. & Harv. I think some doubt attaches to this identification.

G *Sargassum fissifolium* (Mert.) C. Ag. Fishing Rock, mid-tide pool: also in the sublittoral fringe, Lava Pt.

Carpophyllum phyllanthus, C. plumosum, C. maschalocarpum, Durvillea antarctica, and *Hormosira banksii* have all been recorded from the drift (Cotton, Gepp) but there is no evi-

dence that they grow there. The record of *Carpophyllum elongatum* is erroneous, as inspection of the material at Kew and the British Museum shows that the specimens are worn plants of *C. maschalocarpum* (Chapman, in press).

RHODOPHYCEAE

Bangiales

† *Porphyra denticulata* Levr. Previously only reported from Queensland. Sublittoral fringe, Lava Pt., and supralittoral fringe pool.

Nemalionales

G * *Chantransia* sp.

† *Nemalion helminthoides* (Velley) Batters. Very exposed rock faces, Fishing Rocks.

G * *Galaxaura laxa* Kjellm (as *Brachycladia marginata* Schm. in Gepp).

† *Galaxaura arborea* Kjellm. Mid-littoral pool, Meyer I.

† *Galaxaura rudis* Kjellm. Sublittoral, 16 m., Meyer I.

G † *Galaxaura fastigiata* Dcne. (as *G. lapidescens* in Gepp). Sublittoral, 3 m., Meyer I.

G *Asparagopsis taxiformis* (Delile) Collins & Hervey (= *A. sandfordiana*). Very common in sublittoral: extends into sublittoral fringe where exposure and wave action not great.

C G *Delisea fimbriata* (Lamour.) Mont. Sublittoral to 4–5 m., Meyer I. (= *D. pulchra, D. serrata*).

Chaetangium corneum J. Ag.

† *Chaetangium pulvinatum* Levr. Turf, mid-littoral, Fishing Rocks.

Gelidiales

G *Gelidium longipes* J. Ag. Fishing Rock. Mid-tide pool.

Gelidium crinale J. Ag. Turf, lower mid-littoral, Hutchinson's Bluff.

Gelidium pusillum Le Jol. Turf, lower mid-littoral, Hutchinson's Bluff.

Gelidium caulacantheum J. Ag.

C G *Pterocladia capillacea* (Gmel.) Born. et Thur. Fishing Rock, Lava Pt.: sublittoral, 4–8 m. Meyer I.

Cryptonemiales

G * *Peyssonnelia rubra* (Grev.) J. Ag.

C G *Corallina cuvieri* Lmx. Boat Cove (sparse); mid-tide pool, Fishing Rock.

G *Corallina officinalis* L. Mid-tide pool and sublittoral fringe, Fishing Rock; sublittoral, 4–8 m., Meyer I.

Jania rubens Lmx. Mid-tide pool and sublittoral fringe, Fishing Rock. This appears different from the local *J. micrarthrodia.*

G * *Amphiroa anceps* (Lmx.) Dcne.

GC * *Cheilosporum elegans* (Hook. f. & Harv.) Aresch.

Schmitziella cladophorae Chapm. On *Cladophora prolifera.*

Fosliella farinosa. On *Cladophora prolifera,* Lava Pt.

Gigartinales

C * *Plocamium costatum* J. Ag.

G C *Plocamium brachiocarpum* Kütz.

Plocamium angustum J. Ag. On *Pterocladia,* lower mid-littoral, Hutchinson's Bluff.

G * *Gracilaria confervoides* (L.) Grev. Drift.

Ceramiales

G *Martensia elegans* Hering. Sublittoral fringe in *Corallina* turf, Boat Cove: mid-tide pool, Fishing Rocks: sublittoral, 3 m., Meyer I.

Caloglossa leprieurii J. Ag.

G * *Nitophyllum decumbens* J. Ag. Drift.

G * *Euzoniella incisa* (J. Ag.) Falkbg.

G * *Spongoclonium brounianum* (Hook. f. & Harv.) J. Ag.

Microcladia novae-zelandiae J. Ag. Boat Cove, sparse.

G * *Laurencia forsteri* (Mert.) Grev. Drift.

† *Ceramium codii* (Richards) G. Mazoyer. On *Codium adhaerens.* The plants were not fruiting but habit and measurements agreed. Onerahi Bluff.

Centroceras clavulatum (C. Ag.) Mont. Epiphytic on *Pterocladia,* Hutchinson's Bluff; sublittoral, 12 m., Meyer I.

Total marine algae:	Myxophyceae	12
	Chlorophyceae	20
	Phaeophyceae	10
	Rhodophyceae	35

This is not an impressive list considering the variety of habitats available and the fact that the islands clearly lie in a zone where there is a mingling of cold and warm waters.

BRYOPHYTA

The mosses were kindly determined by the late Mr. G. O. K. Sainsbury and the liverworts by Mrs. Hodgson.

Musci

Fissidens pungens C. M. & Hpe.
Fissidens oblongifolius H. f. & W. First record for the Kermadecs.
Rhizogonium ?longiflorum (Mull.) Jaeg.
Rhizogonium spiniforme (Hedw.) Bruch. "Differs from type in having male flowers not synoicous and the perichaetial bracts lengthened. It looks as if some people would consider the Kermadecs plant to be a form of *R. longiflorum*."
Isopterygium minutirameum (C. M.) Jaeg.
Leucobryum candidum (Brid.) H. f. & W.
Echinodium hispidum (H. f. & W.) Jaeg.
Oxyrrhynchium compressifolium (Mitt.) Broth. "This is quite different from other allied forms (*Eurhynchium*) in New Zealand."
Papillaria flaxicaulis (Taylor) Jaeg.
Acanthocladium extenuatum (Brid.) Mitt. "Another first record" for the Kermadecs.
Rhacopilum ?pacificum

Hepaticae

Phaeoceros sp.
Chiloscyphus argutus Nees.
Lophocolea heterophylloides Nees.
Plagiochila sp.
Asterella sp.
Marchantia sp.
Radula sp.

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Feasibility of a Lava-diverting Barrier at Hilo, Hawaii[1]

C. K. Wentworth, H. A. Powers, and J. P. Eaton[2]

The subject of the value and possibility of protecting Hilo Harbor and vicinity from devastation by a lava flow from Mauna Loa is again being given thoughtful consideration by the residents of Hawaii. Those who must weigh the pros and cons of this matter need information, part of which can best be appraised by geologists and engineers. From the geologists' appraisal should come answers to questions such as the following: How often might protection from a lava flow be needed? Is it physically possible to divert a lava flow with a man-made structure? What are the necessary dimensions of such a structure? Of what should it be built? What is its expected useful life?

Various references to cost have been made. Some say that a barrier is justified, regardless of cost; others hold to a strict accounting of supposed risk against cost, amortization, and other factors. These opposed views are widely separated. Many risks could be reduced by astronomical spending, but such spending may be beyond reasonable relation to contemporary life or even to capacity of the community to pay. Though opinions may differ greatly, the criterion of economic justification cannot be ignored altogether.

Much has been written on the subject of a lava barrier for Hilo. The latest and most comprehensive review and discussion is by Gordon A. Macdonald (1958). His greatest emphasis is laid on the matter of a barrier system to be constructed across the slope above Hilo to divert the course of an approaching lava flow. He concludes that a system of barriers can divert the course of a lava flow.

The conclusions reached in this report differ in this matter from those expressed by Macdonald because different evaluations are made of the same few facts available for appraisal. Among the most important of these different evaluations, this report concludes that the minimum condition for the successful functioning of a diversionary system is the construction of a channelway adequate to conduct the lava flow along the chosen route behind the barrier system. An adequate channel may exceed 2 mi. in width with rock excavation in excess of a 400-ft. depth along the upslope margin, even with a barrier 60 ft. high along the downslope margin. Facts needed to design the channel system and to appraise the amount of funds that can prudently be invested in it are imponderable—facts such as the volume of flow to be expected and the probable frequency of hazard. In the face of such imponderables, a downslope diversionary system is unrealistic; it would seem prudent to rely on, and plan for, defensive actions that can be taken during an eruption, such as causing distributary flows at or near the vent.

Forecasting Activity

The waxing and waning of volcanic activity shown in the geologic history of Mauna Loa makes it impossible to give a dependable prediction of the *probable* hazard to Hilo from lava flows. The *possible* hazards cover a great range: Hilo might be obliterated by another eruption from the same vicinity as the prehistoric eruptions that formed the Halai Hills (see Fig. 1); or it is possible that no future lava flow will ever reach Hilo. Since Hawaiian oral history began, perhaps about A.D. 1100, only one lava flow from Mauna Loa, that of 1881, reached the vicinity of Hilo.

It is natural to predict future events on the premise that events of the best-known past will be repeated; in this instance, the history of Mauna Loa's activity since 1843. How disastrously wrong such a prediction can be was emphasized by the eruption in 1960 of the Kilauea lava flow in Puna. After the devastating flow in 1955, no further outbreak in that region was to

[1] Publication authorized by the Director, U. S. Geological Survey. Manuscript received October 24, 1960.

[2] U. S. Geological Survey, Hawaiian Volcano Observatory, Hawaii National Park, Hawaii.

be expected for several decades, based on the spacing of recent known eruptions: 1740?, 1793?, 1840, and 1955 (Macdonald, 1941). Forecasts of Mauna Loa activity based on an even shorter period of time may be equally wrong; in fact, an inspection of a longer record shows that the activity of Mauna Loa waxes and wanes in a manner that gives no useful basis for predicting the frequency of future activity. In the 180 years since 1780 there have been 20 lava flows from the flanks of Mauna Loa; in the preceding 600 odd years covered by Hawaiian oral traditions there apparently were no lava flows from Mauna Loa; and, representing activity previous to A.D. 1100, 60 different ancient cinder cones can be found that indicate flank eruptions that took place over an unknown span of time. There is no geological basis for predicting how long the present epoch of frequent eruption may last; it may continue or it may have run its course.

The evidence for the dormancy of Mauna Loa during about 600 years covered by Hawaiian oral history is considered here in some detail, as it has not had the attention in the literature that it deserves. It consists of the evaluation of observations by early explorers and of geologists and evaluation of Hawaiian oral history and mythology.

Members of Captain Cook's expedition in 1778–79, particularly John Ledyard who attempted to climb the mountain, noted that Mauna Loa was a volcano and described features on the slopes " . . . that had every appearance of past eruption and fire. . . . But there is no tradition among the inhabitants of any such circumstance" (Hitchcock, 1909: 61–62).

Archibald Menzies, the botanist on one of Vancouver's expeditions, climbed to the summit crater of Mauna Loa in February, 1794; he contrasts "the Mountain" Mauna Loa with "the Volcano" Kilauea in his descriptions (Hitchcock, 1909: 68–72).

William Ellis, a British missionary who knew the Polynesian language, explored Hawaii in 1823 and queried the Hawaiians about volcanic activity. They had no oral history of lava flows from Mauna Loa but reported that Kilauea had been active from "time immemorial" and that some part of the lands of Kau and Puna had been devastated by a lava flow during the reign of every King (Hitchcock, 1909: 163–164).

The United States exploring expedition under Captain Wilkes spent nearly a month on the summit of Mauna Loa in the winter of 1840–41, having traversed the northeast ridge in the ascent (at that time, only one of the known historic eruptions had broken out from this region). They reported that the whole area was of lava, chiefly of very ancient date (Hitchcock, 1909: 83).

A large area of the southwest ridge of Mauna Loa was explored by R. H. Finch of the U.S. Geological Survey during December, 1925. He observed, "The lava on the southwest flank of Mauna Loa may well be divided into two ages: recent (within the last 100 to 150 years, say), and old. Lava flows of various ages showing a uniform gradation in weathering between the oldest and newest flows are not to be found" (Finch, 1925: 90).

There is thus some geologic evidence for a considerable period of dormancy of Mauna Loa, implied by the lack of mention of Mauna Loa flows in Hawaiian oral history. Moreover, recent seismological evidence that Kilauea's lava rises from a zone about 60 km. beneath the region between the Kilauea caldera and Mauna Loa's northeast rift zone raises the possibility that both volcanoes are fed from the same source and that when one is in a period of unusual activity the other erupts infrequently. Such alternation in activity between the two volcanoes over century-long intervals is suggested by the historic evidence quoted above.

However, the Hawaiians were well aware of the fact that Mauna Loa was a volcano; many of their myths describing the activities of the demigods were explanations of volcanic features they found on the slopes of Mauna Loa. Pre-Hawaiian lava flows on the southwest slope are explained in the legend of "Na Pu'u o Pele" (Westervelt, 1916: 22–26); the lava flows that bank against the north slope of Mauna Kea were, to the Hawaiians, evidence of legendary conflicts between Pele and the snow-goddesses (Westervelt, 1916: 62); and the most recent lava flow in the forest south of Hilo was, to them, a record of the battle between Hi'iaka and Pana-'Ewa (Westervelt, 1916: 96–103). In

contrast, the lava island in Hilo Bay called Coconut Island was fished up from the sea by the demigod Maui (Westervelt, 1916: 28), apparently not associated in Hawaiian minds with the demigods to whom they attributed volcanic phenomena.

DIVERSION SYSTEM TECHNICALLY POSSIBLE

All who have considered the problem have agreed that a solution to containing a lava flow does not lie in impounding lava behind a dam; the topography is not favorable and the total amount of lava that would need to be stored cannot be estimated. The solution is sought, therefore, in some manner of diverting the course of flow. A lava flow following a natural channel can be entirely diverted along a chosen alternate channel if one fundamental condition is met—the artificial channel must be able to carry the lava away from the point of interception as rapidly as it is delivered there by the natural flow.

The average gradient of such a diversion channel will, of necessity, be considerably less than the average gradient of the natural slope across which it is constructed. To offset the unfavorable loss of gradient, the built channel must offer less obstruction in its floor, such as irregularities and vegetation, and provide space for a greater cross-section of flow. It is not enough to consider that a cross-section of a diversion channel is adequate by allowing an added area to compensate for the reduced gradient on the basis only of gravity flow of a liquid. Allowance must be made also for the capacity of the lava flow to transmit enough heat to maintain its liquidity. This differential term in the equation works against a wide flow, even though its greater width might sufficiently compensate reduced depth for water. If these conditions are met, the channel will direct the movement of the flow, and the barrier need only confine the downslope margin, not act as a dam across the flow.

However, if lava behind the barrier is ponded to a considerable depth (50 ft. or so), the possibility that it might inject itself through the barrier or its foundation cannot be overlooked. Such an engineering accident was responsible for the early failure of a barrier constructed during the 1960 eruption of Kilauea.

DESIGN OF THE DIVERTING SYSTEM

The designer of a system of structures to divert flowing lava must know the probable maximum rate of delivery of lava that can be expected to enter the system. Here again, geologic experience cannot predict the probable requirements, it can only point out the possible maximum load. If the outbreak takes place within 10 or 15 mi., lava may be expected to enter the system at a rate of about 25,000,000 cu. yd/hr, based on the observations made on the Mauna Loa eruption of 1950, the most voluminous eruption that has been sufficiently documented (Finch and Macdonald, 1953). Should the designer anticipate the voluminous load from a nearby eruption? What are the data upon which to make the decision?

The pre-Hawaiian lava flows that form the south shore of Hilo Bay (see Fig. 1) appear to have come from vents along the lower part of the northeast rift, according to current studies of recent air photographs and some reconnaissance field identifications. The topographic ridge built by these and similar eruptions is the south boundary of the topographic trough that slopes into Hilo Bay. Any future eruption along this rift line below an altitude of about 3,500 ft. will lie on the south side of the ridge, and its lava flows thus would be directed away from Hilo Bay; an eruption along this zone above about 3,500 ft. will be more than 15 mi. from Hilo. Any source vent closer to Hilo than 15 mi. would have to break through the flank of Mauna Loa considerably to the north of the zone of old cinder cones that mark the lower part of the northeast rift. However, Stearns and Macdonald (1946: 70) reasoned that the vents in Hilo (Halai Hills) lie on a branch of the northeast rift, and Macdonald restated the supposition in 1958 (p. 259). An eruption on any part of this supposed branch of the rift zone will be in the trough leading to Hilo; such an eruption must be expected geologically, even though there are no existing vents along this line between Hilo (Halai Hills) and a point 22 mi. from Hilo at

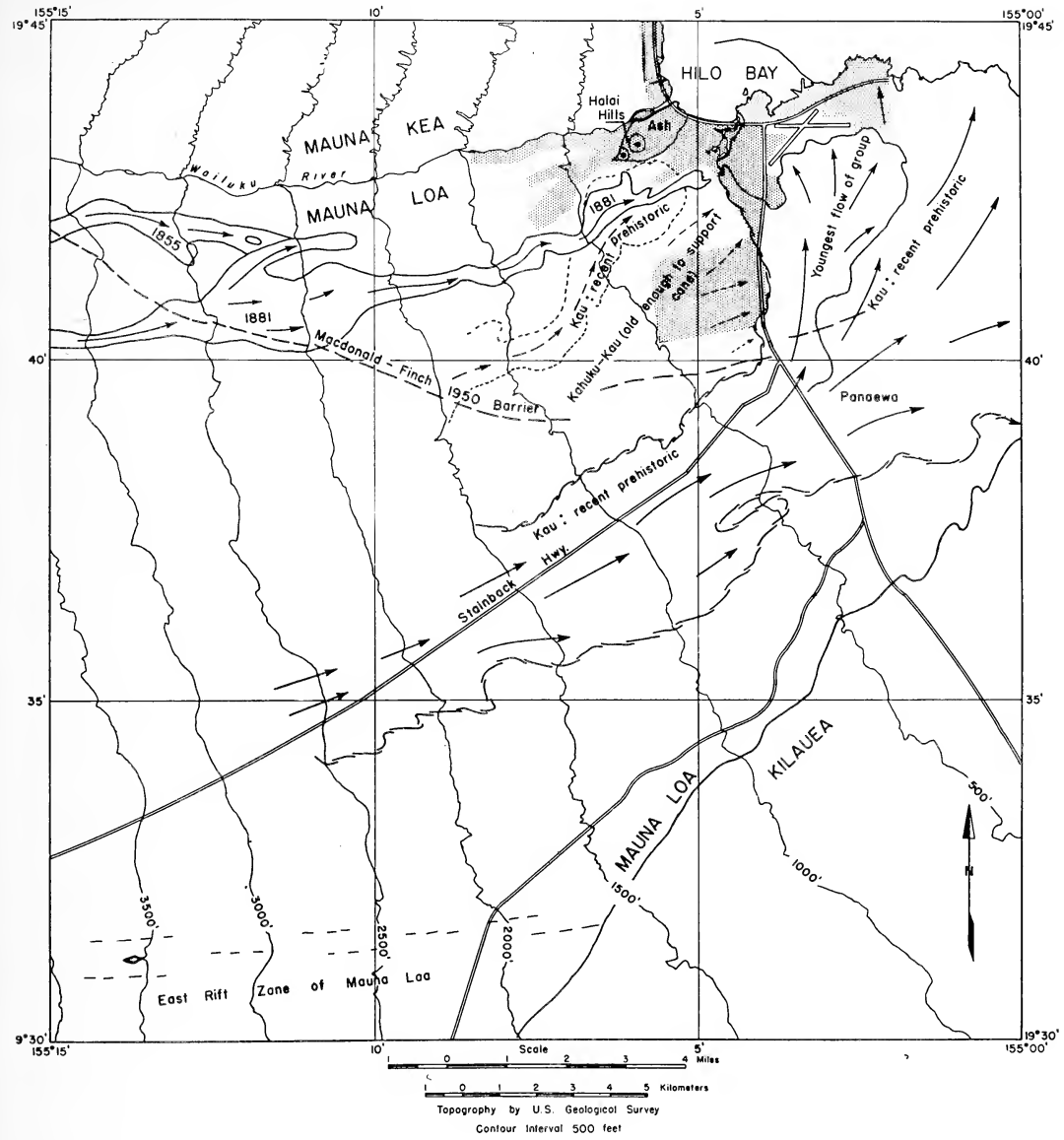

FIG. 1. Map of the vicinity of Hilo, Hawaii, showing historic and recent prehistoric lava flows from Mauna Loa that approached Hilo Bay. Shaded area represents present extent of the city of Hilo.

an altitude of 6,800 ft. Even if it is assumed that the reasoning of Stearns and Macdonald is incorrect (and there is no compelling geological basis for such an assumption), and that the supposed branch of the rift zone does not exist, there remains strong geologic precedent for an outbreak through any flank area away from a known rift zone. Of the 72 known flank eruptions, 18, or one-fourth, have broken through the mountain flank several miles away from any known rift zone. The eruption of 1877, above and in Kealakekua Bay (Hitchcock, 1909: 115), broke out as far from a rift zone as it is possible to be. There has been no eruption, in

the past, within 15 mi. upslope from the probable site of a diversion structure, but there is no known geologic reason why an eruption may not break through in this area. A reasoned decision about the necessary barrier design cannot be made on such data; the decision must be based on other considerations.

Another, and completely unrelated, problem of design for which no geologic or engineering solution is possible rises from certain characteristics of a lava flow (Wentworth, 1954). Every flow of lava inevitably sends out distributary flows from time to time and from place to place along its course, as one way of responding to frequent large fluctuations in the amount and rate of eruption of lava at the source vent. Therefore, it may be expected that more than one flow of lava will enter the channel of the diversion system during any one eruption. Inasmuch as mobile lava becomes immobile rock as soon as it cools slightly, a considerable amount of any lava that enters the channel system will solidify there and form an obstruction in the channel. Thus, any subsequent flow of lava that enters the channel system at a point upgrade will have to override this obstruction in order to keep on moving downgrade. If the channel system has been built with enough capacity, the overriding flow will be contained and the system will continue to function; if the system has too small a capacity at this point, the barrier wall of the channel will be overrun at the obstacle and the diversion system will fail to function.

At the designing stage of an adequate diversion system, it is obviously impossible to anticipate the point at which a future first lava flow will enter the system, to estimate the magnitude of the obstruction that it will form, or to appraise the amount of lava that may have to pass over the obstruction. The designer can cope with this situation only by overdesigning the entire system. He can only guess how much to overdesign:—twofold?—tenfold?

In considering design of barriers and diversion channels, the tendency of liquids adjacent to a dam to cause uplift pressure and to burrow through should be realized. To allow for such tendency is standard practice in designing dams, because some have failed in this way. Lava barriers have also failed in this way, as was recently observed in some instances at Kapoho. However, in the case of a massive barrier built of well-compacted rock and soil, this is thought to be a very remote contingency because of the cooling effect. Lava might retain liquidity through tenuous openings for a distance of 200 or 300 ft. but would seem unlikely to do so through 1,000 ft. or more except in a pre-established tube. Such an accident is not entirely dismissable, however.

SAMPLE ESTIMATES OF DIVERSION CHANNEL DIMENSIONS

We can neglect for the moment the imponderable matter of overdesign and consider the dimensions required to convey two sample lava flows that may be assumed to move as simple flow units.

The average natural gradient of the trough that leads to Hilo, which must be intercepted by the diversion system, is between 250 and 300 ft/mi. The diversion channel probably could be laid out with an average gradient of no more than 200 ft/mi. Estimates of the velocity of movement of lava flows on comparable low gradient can be made from published descriptions of previous flows. The hot, mobile lava near the vent of the 1954 eruption of Kilauea (Macdonald and Eaton, 1954) moved at rates not less than 400 yd/hr. A channel designed to move 25,000,000 cu. yd. of hot, mobile lava at this velocity would need to provide space for a flow cross-section of 63,000 sq. yd. If a containing barrier on the downslope margin of the channel were built high enough to give an average depth of flow of 20 yd. in the channel, the width of the channel would be 3,150 yd. (approaching 2 mi. wide), and the maximum rock excavation at the upslope margin would be greater than 400 ft.

A different example: the relatively cool and viscous lava of the 1926 flow that destroyed the beach village of Hoopuloa (Hawaiian Volcano Observatory, 1926) moved at rates not less than 60 yd/hr. A similar relatively cool flow from a distant vent reaching the diversion system at a rate of 2,000,000 cu. yd/hr would require a channel cross-section of nearly 34,000 sq. yd. to

carry the load at 60 yd/hr velocity. Assuming an average depth of 20 yd., the width of channel required is about 1,700 yd. (1 mi.) and the upslope would exceed 200 ft.

These examples have neglected the overdesign necessary to accommodate the transportation of distributary flows.

CHANGING THE MOVEMENT PATTERN OF LAVA FLOWS BY BOMBING

It has long been understood by observers of Hawaiian lava flows that the course and progress of a flow can be radically altered by breaching the levee bank of the main feeding channel. Macdonald (1958) presents an excellent discussion and evaluation of the matter which need not be repeated here. He concludes that efforts to divert the flows by bombing should be made in the event of a threat to Hilo, but that a barrier system also should be constructed as insurance against failure of the bombing effort, particularly in the event that a voluminous, fast moving flow would overrun the area before bombing could be carried out. However, it would seem from the discussion in previous paragraphs that an artificial diversion system of dimensions adequate to cope with a voluminous, fast moving flow would be expensive beyond prudent economic justification. Thus, it would seem that the hazard of being overrun by lava is one that must be accepted and lived with, perhaps analogous to the acceptance of earthquake hazards by Tokyo and cities in other earthquake areas.

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Variations in the Lava of the 1959 Eruption in Kilauea Iki[1]

GORDON A. MACDONALD and TAKASHI KATSURA[2]

IN RECENT YEARS the Hawaiian Islands have become of great importance in studies concerned with igneous petrogenic theory. This is partly because of the total absence in that region of sialic crust that might affect the formation of other rock types by its assimilation in rising magma. Partly, also, it is because of the extensive lateral and vertical exposure of successions of rocks, the structural and stratigraphic relationships of which are now well known. These conditions have attracted to the area workers from many parts of the world, and progress in knowledge of Hawaiian rocks has been rapid. The knowledge is, of course, the accumulation of the findings of many workers, starting with the visit of J. D. Dana to the islands in 1840, as a member of the U. S. Exploring Expedition. Outstanding among recent workers are Hisashi Kuno of Tokyo University, P. Niggli of the University of Zurich, C. E. Tilley of Cambridge University, H. S. Yoder of the Geophysical Laboratory of the Carnegie Institution of Washington, and H. A. Powers of the United States Geological Survey.

During 1960 and 1961 two studies have largely confirmed, but also extended and somewhat modified, the previous petrogenic picture. In April, 1960, the junior author of this paper, on leave from the Tokyo Institute of Technology, commenced a series of chemical analyses of Hawaiian lavas at the University of Hawaii under a National Science Foundation grant to the senior author. At the end of March, 1961, approximately 150 new analyses, primarily of the hitherto largely neglected "primitive" lavas of the Hawaiian volcanoes, had been completed. These have helped fill important gaps in the basic knowledge of Hawaiian rocks. Study of them is continuing.

During July, 1960, a core hole was drilled in the crust of the recently erupted lava pool in Kilauea Iki crater of Kilauea volcano, and penetrated into the molten lava beneath. The results of study of the drill-hole samples and samples of the earlier lava of the eruption are reported in this paper.

Acknowledgments. The core hole in the crust of the Kilauea Iki lava pool was drilled for the Lawrence Radiation Laboratory of the University of California in cooperation with the University of Hawaii, and the chemical analyses of the core samples were done at the University of Hawaii for the Lawrence Radiation Laboratory. The entire program is a part of the Lawrence Radiation Laboratory's Plowshare Program for the development of peaceful uses of atomic energy. The results of other aspects of the investigation will be published by members of the staff of the Lawrence Radiation Laboratory.

The drilling was done by a crew in the employ of Nat Whiton of Honolulu, under the general supervision of Walter Bennett and Donald E. Rawson of the Lawrence Laboratory. General scientific supervision was furnished by Macdonald. Thanks are due to the National Park Service for permitting the drilling for scientific purposes within Hawaii National Park, and to the Lawrence Radiation Laboratory for permitting us to publish the chemical analyses and other data on the core samples.

The sample of Pele's hair analyzed was collected and given to us by Mr. H. Ikawa, of the Department of Agronomy, University of Hawaii.

Two analyses (S-1 and S-2) in Table 1 are by J. H. Scoon of Cambridge University.

We wish to express our thanks to A. T. Abbott, of the University of Hawaii, for critical reading of the manuscript.

HAWAIIAN ROCK SUITES

In the classical Mull Memoir (1924), E. B. Bailey and his associates distinguished three principal rock types, which they termed the plateau, central porphyritic, and central nonporphyritic types. In 1933, W. Q. Kennedy applied the names *olivine basalt* and *tholeiite* to the first and

[1] Hawaii Institute of Geophysics, Contribution 23. Manuscript received March 21, 1961.

[2] University of Hawaii.

last types, respectively. In 1935, H. A. Powers recognized the presence of both these types in the Hawaiian Islands, though he did not employ the same terminology. Later Macdonald (1949*a*: 88) also pointed out that, although it had been thought by Kennedy to be absent from the oceanic areas, tholeiite is present in Hawaii. In 1955, Powers emphasized the essentially silica-saturated nature of the lavas of Mauna Loa and Kilauea. Although it had been anticipated to some extent by Powers (1935), C. E. Tilley (1950) was the first to definitely point out the presence of two distinct rock series in Hawaii. These he termed the *tholeiitic* and *alkali olivine basalt* series.

Tholeiite has been defined (Tilley, 1950; Kuno *et al.,* 1957) as a rock essentially saturated or slightly oversaturated with silica in which magnesian olivine bears reaction relationship to orthopyroxene and Ca-poor clinopyroxene. In contrast, alkali olivine basalt was defined as an undersaturated rock in which magnesian olivine and Ca-rich clinopyroxene undergo parallel crystallization. The characteristic groundmass pyroxene of tholeiite is pigeonitic, though the wollastonite content ranges from about 40 per cent to less than 10 per cent. That of alkali olivine basalt is Ca-rich augite. Hypersthene is present in some tholeiites.

Recently Kuno (1960) has pointed out the wide distribution of basalts resembling the central porphyritic type of Mull in their richness in alumina, but differing from it in being essentially nonporphyritic. High-alumina basalt of this type has not been found in the Hawaiian Islands, though some rocks containing abundant phenocrysts of feldspar are moderately high in alumina.

The predominant lavas of the great bulk of the visible part of the Hawaiian shield volcanoes contain scattered to moderately abundant phenocrysts of olivine, commonly as much as 5 mm. in diameter. These rocks have been called "olivine basalt" by Macdonald (1949*a*, *b*). Typically, however, the olivine phenocrysts are partly resorbed, and obviously were reacting with the remaining liquid at the time of consolidation of the rock. Chemical analyses show many of these rocks to be essentially saturated in silica, and the pyroxenes are lime-poor. They are thus typical tholeiites. They grade into other rocks that are otherwise similar but contain normative olivine. The extreme of the latter group is picrite-basalt of oceanite type, which may contain more than 50 per cent olivine phenocrysts. These rocks are chemically undersaturated with silica, and even with the attainment of complete equilibrium on crystallization should contain modal olivine. As in the more silica-saturated types, however, phenocrystic olivine commonly has separated in excess of its stoichiometric proportion, and was undergoing reaction with the liquid at the time of consolidation, as is indicated by their partial resorption. The groundmass pyroxene is largely or entirely lime-poor augite and pigeonite. Thus, although they are undersaturated with silica and therefore not true tholeiites, these rocks conform with Tilley's definition of tholeiite as a rock in which magnesian olivine bears a reaction relationship to Ca-poor pyroxene, and the entire group from the nonporphyritic true tholeiites to the picrite-basalts of oceanite type may be termed the *tholeiitic suite.*

Both Powers (1955) and Macdonald (1944) have pointed out that the variations within the tholeiitic suite can be largely accounted for by settling of olivine phenocrysts in the magma, though movement of minor amounts of pyroxene and plagioclase also probably are involved (Muir and Tilley, 1957; Macdonald, 1949*b*: 1576). Locally differentiation has yielded small amounts of iron-rich basalt and granophyre (Kuno *et al.,* 1957).

The major tholeiitic part of the Hawaiian shields is succeeded by a relatively small amount of lavas of other types, including alkali olivine basalt, picrite-basalt of ankaramite type, hawaiite (Macdonald, 1960), mugearite, and trachyte. This group may be called the *alkalic suite,* because of its relationship to alkali olivine basalt, and because the great majority of the members of the group contain a larger proportion of alkalies than do members of the tholeiitic suite that contain the same amount of silica. The lavas of the alkalic suite constitute only a few per cent of the total bulk of the Hawaiian volcanic mountains. The nature of the transition from the tholeiitic to the alkalic suite will be discussed in detail in a future report describing the results of the recent chemical analyses.

A still later group of lavas, which may be called the *nephelinic suite,* consists characteristically of nepheline basalt and melilite-nepheline basalt, but includes also basanites, and alkali olivine basalts ("linosaites") in which nepheline is present in the norm though not in the mode. The nephelinic suite is in general separated from the rocks of the other groups by a profound erosional unconformity (Stearns, 1946: 22).

THEORIES OF ORIGIN OF HAWAIIAN ROCK SUITES

There appears to be little or no question that the tholeiitic magma originates in the upper part of the earth's mantle, probably at a depth of about 30 or 40 mi., and that variations within the suite are largely or entirely the result of crystal differentiation. The same degree of certainty does not extend to the alkalic suite. Macdonald has previously attributed the formation of the more alkalic members of the alkalic suite to differentiation of a parent magma corresponding approximately in composition to the average basalt of Kilauea (Macdonald, 1949*a*: 92; Stearns and Macdonald, 1946: 205), or to an average of basalts from all Hawaiian volcanoes (Macdonald, 1949*b*: 1569). The former average corresponds with tholeiite only slightly undersaturated with silica. The latter average included alkali olivine basalts, and therefore is a little higher in alkalies and less saturated with silica than the Kilauean average. Calculations indicated that the alkalic rocks could be derived from either parent by crystal differentiation. To do so, however, it was necessary to hypothesize the separation of a large amount of pyroxene (both diopside and hypersthene) from the magma. Derivation of alkali olivine basalt per se was not considered, because it was not recognized as an independent rock type. The possibility of other differentiation processes, such as alkali transfer by volatiles, was also recognized.

Tilley (1950: 44–45) also attributed the various members of the alkalic rock suite to crystal differentiation of tholeiite, separation of hypersthene in place of olivine producing the alkali olivine basalt. Powers (1955) agreed to the importance of the movement of olivine crystals in producing the variations among the tholeiitic basalts, but pointed out, as indeed he had earlier (Powers, 1935), that crystal differentiation alone is inadequate to produce alkali olivine basalt from a *saturated* tholeiite.

It certainly is true that desilication of a magma by crystal differentiation can only result from the removal of crystals containing more silica than the magma. The removal of pyroxene from tholeiite can perpetuate a state of undersaturation in silica, but cannot bring it about. No mineral containing more silica than a saturated tholeiite magma is likely to form and separate except during the very latest stages of crystallization. Provided, however, that a distinctly undersaturated tholeiitic magma exists as a liquid, crystallization of pyroxene can not only perpetuate the undersaturation, but increase it. Murata (1960) has suggested that alkali olivine basalt is derived in this way from undersaturated tholeiitic magma.

Kuno *et al.* (1957: 212) agree with Powers that crystal differentiation cannot produce alkali olivine basalt from tholeiite. Instead, they assume the existence of two independent primary basalt magmas, tholeiite and alkali olivine basalt, formed by partial melting of peridotite at different levels in the mantle, incongruent melting of pyroxene at the higher level supplying extra silica for the tholeiite. More recently, Kuno (1960) has hypothesized still a third primary magma, high-alumina basalt, produced by melting in the mantle at a depth intermediate to the other two levels.

For several reasons, the existence of two primary basalt magmas in Hawaii appears improbable. Chemical analyses demonstrate a complete intergradation of the two types in composition (Figs. 1 and 3). Furthermore, it seems unlikely that melting at a deeper level in the mantle would produce a magma richer in alkalies than would melting at a shallower level. If anything, the reverse would be expected. These arguments are far from conclusive but, particularly when it is remembered that the rocks of the alkalic suite comprise only a very small proportion of the total, they do suggest that in some way alkali basalt magma is produced from tholeiitic magma, rather than having a wholly independent origin.

KILAUEA IKI LAVA

The pool of lava in Kilauea Iki crater, a pit crater immediately adjacent to the east edge of Kilauea caldera, was accumulated during the eruption that lasted from November 14 to December 20, 1959. The eruption consisted of 16 separate eruptive phases, from 2 to 167 hr. in length, separated by quiet periods of 8–101 hr. duration during which part of the lava flowed back into the vent from which it had issued (Macdonald, in press). Lava from fissures on the southwest wall of the crater about 300 ft. above the pre-eruption floor poured down the crater wall and formed a pool that gradually deepened until its surface was above the level of the original vents. Temperature measurements up to nearly 1200° C. were obtained on the lava fountain at the vent (Richter and Eaton, 1960). During eruptive phases lava was added to the crater fill partly by injection beneath the crust and partly by spreading over the previous crust. A new crust formed quickly on the molten lava as each successive outpouring covered the crater floor, but from time to time broke up and foundered during convective overturns in the liquid. The latter suggests that submerged crusts of previous eruptive phases had been largely destroyed (possibly accumulating as sunken fragments at the bottom), leaving a pool of melt that was essentially continuous from bottom to top. The final depth of the pool is approximately 380 ft.

In July, 1960, 7 months after the end of the eruption, the drill hole already mentioned was sunk into the solid crust of the lava in Kilauea Iki crater. Continuous core samples were taken, and cutting samples were preserved from successive drill runs to supplement the cores in intervals in which core recovery was poor. On July 25 the drill bit encountered very viscous semisolid material at a depth of 19.1 ft., and at 19.5 ft. it entered underlying liquid lava and started to sink into it. The tools were immediately removed from the hole, and a sample of the liquid that had congealed in it was removed from the bit. Additional samples were taken the next day by thrusting the drill pipe, without a bit, down into the liquid and withdrawing it. By the morning of July 28 liquid lava had risen in the hole to a level 18.7 ft. below the surface.

Eight samples from the drill hole, and one of the surface crust adjacent to it, have been analyzed chemically. They are listed in Table 1. Three analyses of lava extruded earlier in the eruption also are given. Of these, one is of Pele's hair wafted from the crater during the first days of the eruption. The other two (S-1 and S-2), by J. H. Scoon of Cambridge University, represent lava poured into the crater and spatter thrown onto the crater rim during the first eruptive period, between November 14 and 21.

Analyses 9 and 10 are of samples of the liquid lava that underlay the solidified crust. It will be noted that the two are not identical. Sample 10 is decidedly richer in alkalies. Sample 9 contains many more phenocrysts of olivine than sample 10, and is presumed to have come from a slightly lower level in the liquid.

Column 1 of Table 1 is an analysis of Pele's hair formed at the beginning of the eruption. Scattered phenocrysts of olivine were present in the Pele's hair, but none were included in the sample analyzed. The sample consisted essentially wholly of glass, even microlites being almost entirely absent. Therefore, the analysis represents magma that was completely liquid at the time of eruption. The norm indicates a notable degree of undersaturation of the liquid in respect to silica. It has generally been assumed that normative olivine in tholeiitic rocks is largely the result of addition to the magma of solid crystals of olivine that have sunk from higher levels. In the case of the Pele's hair of analysis 1 the undersaturation is not, however, the result of inclusion of olivine crystals in the analyzed sample. The liquid phase of the magma was itself undersaturated. Yet its very low content of alkalies and alumina mark it clearly as a member of the tholeiitic suite. It is close to the value suggested by Bowen (1928: 164) as the limit of undersaturation in completely liquid basaltic magmas, though less undersaturated than some rocks believed by Drever (1956) to have been derived from completely liquid magmas.

In thin section the samples from the upper 17 ft. of the drill hole differ from each other almost entirely in the abundance of olivine phenocrysts, which range from about 10 per cent in the sample from 16.5 ft. to 40 per cent in that from 7.5 ft. The latter is a picrite-basalt of oceanite

TABLE 1

CHEMICAL ANALYSES OF LAVAS OF THE 1959 ERUPTION IN KILAUEA IKI

	1	2	3	4	5	6	7	8	9	10	11	S-1	S-2
SiO_2	48.82	46.77	46.99	44.58	45.61	45.63	47.24	48.25	48.43	47.73	38.85	48.91	48.13
Al_2O_3	13.42	12.04	12.14	9.25	9.06	10.58	11.14	12.90	13.00	14.58	0.31	12.42	11.62
Fe_2O_3	1.70	1.72	2.55	1.27	1.32	1.85	1.41	1.78	1.32	1.36	0.55	1.34	1.27
FeO	9.90	9.95	9.19	10.76	10.49	10.26	10.22	9.88	11.25	12.99	12.21	10.23	10.40
MgO	9.00	14.85	14.33	23.46	21.48	18.41	15.66	11.39	9.39	6.01	47.69	10.96	13.78
CaO	11.32	9.89	9.90	7.18	7.79	8.40	9.56	10.38	10.03	8.92	0.00	10.44	9.64
Na_2O	2.25	1.53	1.51	1.10	1.28	1.31	1.53	1.75	2.10	2.43	0.00	2.20	2.04
K_2O	0.58	0.38	0.40	0.29	0.30	0.38	0.39	0.45	0.60	0.98	0.00	0.54	0.50
H_2O+	0.02	0.19	0.28	0.10	0.27	0.18	0.23	0.35	0.04	0.09	0.15	0.02	0.01
$H_2O—$	0.02	0.04	0.06	0.04	0.20	0.23	0.14	0.07	0.25	0.00		0.00	0.00
TiO_2	2.77	2.28	2.24	1.73	1.77	2.05	2.20	2.52	2.98	3.95	0.05	2.64	2.38
P_2O_5	0.24	0.24	0.25	0.19	0.16	0.25	0.15	0.28	0.32	0.43	0.00	0.25	0.23
MnO	0.18	0.18	0.18	0.18	0.17	0.18	0.16	0.18	0.18	0.20	0.16	0.15	0.18
Total	100.22	100.06	100.02	100.13	99.90	99.71	100.03	100.18	99.89	99.67*	99.97	100.10	100.18
NORMS													
or	3.34	2.22	2.22	1.67	1.67	2.22	2.22	2.22	3.34	6.12	.....	2.78	2.78
ab	18.86	13.10	12.58	9.43	11.00	11.00	13.10	14.67	17.82	20.44	.....	18.34	17.29
an	24.74	24.74	25.30	19.18	18.07	21.96	22.24	26.13	24.19	26.13	.....	22.80	21.13
di wo	12.30	9.86	9.63	6.61	8.12	7.89	10.21	9.86	9.86	6.38	.....		
di en	7.50	6.70	6.60	4.70	5.70	5.50	7.00	6.30	5.80	2.90	.....	22.24	20.43
di fs	4.09	2.38	2.24	1.32	1.72	1.72	2.38	2.90	3.56	3.43	.....		
hy en	9.30	10.20	13.80	10.00	9.40	10.70	11.30	15.50	12.60	8.40	.....	16.08	12.83
hy fs	5.02	3.56	4.49	2.77	2.64	3.30	3.96	7.13	7.79	10.16	.....		
ol fo	3.99	14.14	10.64	28.35	26.53	20.86	14.63	4.69	3.57	2.59	.....	10.25	18.70
ol fa	2.55	5.71	3.88	8.46	8.67	7.14	6.02	2.34	2.55	3.57	.....		
mt	2.55	2.55	3.71	1.86	1.86	2.78	2.09	2.55	1.86	2.09	.....	1.86	1.86
il	5.32	4.41	4.26	3.34	3.34	3.95	4.26	4.71	5.78	5.62	.....	5.02	4.56
ap	0.67	0.34	0.34	0.34	0.34	0.34	0.34	0.67	0.67	1.01	.....	0.67	0.51

1. Pele's hair, free of olivine phenocrysts, erupted during the early stages of the eruption; collected by H. Ikawa, Nov. 22, 1959. T. Katsura, analyst.
2. Surface of lava crust adjacent to Lawrence Radiation Laboratory drill hole. T. Katsura, analyst.
3. Core from drill hole at depth of 4 ft. T. Katsura, analyst.
4. Core from drill hole at depth of 7.5 ft. (picrite-basalt of oceanite type). T. Katsura, analyst.
5. Core from drill hole at depth of 7.7 ft. (picrite-basalt of oceanite type). T. Katsura, analyst.
6. Cuttings from drill hole in interval between 12 and 14 ft. depth. (No core was recovered.) T. Katsura, analyst.
7. Core from drill hole at depth of 13.9 ft. T. Katsura, analyst.
8. Core from drill hole at depth of 16.2 to 16.8 ft. T. Katsura, analyst.
9. Liquid lava from beneath crust. T. Katsura, analyst.
10. Liquid lava from beneath crust. T. Katsura, analyst.
11. Olivine phenocryst from picrite-basalt at depth of 7.5 ft. in drill hole. T. Katsura, analyst.

S-1. Olivine basalt lava poured onto floor of Kilauea Iki between November 14 and 21, 1959. J. H. Scoon, analyst. (Tilley, 1960: 494.)

S-2. Spatter thrown onto south rim of Kilauea Iki crater between November 18 and 21, 1959. J. H. Scoon, analyst. (Tilley, 1960: 494.)

type. It is believed to be the olivine-enriched lower part of the last lava to spread across the crater floor. No phenocrysts other than olivine are present in any of the samples. The groundmass is intergranular to intersertal, and consists of calcic plagioclase, averaging about An_{65}, monoclinic pyroxene, iron ore, and locally interstitial glass. The pyroxene ranges from augite with an optic axial angle of at least 50° to pigeonite with an angle close to 0°. No silica mineral was observed. Glass increases gradually in samples below 15 ft., suggesting that interstitial fluid in the rocks was chilled at the time of sampling.

Samples 9 and 10, the congealed liquid picked up in the end of the drill pipe, are much alike except for greater abundance of olivine phenocrysts in the former. Both consist predominantly of glass. Around the edge a zone 1–2 mm. thick consists of about 85 per cent pale brown glass with scattered microlites of feldspar, pyroxene, and magnetite. This appears to have resulted from quick chilling of the liquid against the steel pipe. The rest of the core consists of black to deep brown glass, containing phenocrysts of olivine up to 1.5 mm. long, and small grains of plagioclase and pyroxene, locally clotted together in glomeroporphyritic texture. The larger olivines have $(-)2V = 80°\pm$. They show moderate skeletal development, and little or no signs of resorption. The larger pyroxene grains are lime-poor augite, with $(+)2V = 50°\pm$. Some smaller grains have $(+)2V = 30°\pm$. Small grains of magnetite are present, and the dark color of the glass appears to result from very finely dispersed iron ore. The proportion of glass is variable, but averages 50–60 per cent.

All but one of the Kilauea Iki samples are quite definitely tholeiitic. The single exception is sample 10, which is transitional from the tholeiitic to the alkalic rocks. In Figure 2, in which total alkali content is plotted against silica, sample 10 lies just within the alkalic basalt field. On the basis of very quick inspection of the analyses, Dr. Kuno has suggested (oral communication, March 2, 1961) that sample 10 represents an iron- and alkali-enriched segregation similar to the veinlet from a flow in the wall of Kilauea caldera described by him and his associates (1957: 187). Indeed, in Figure 1 the point representing the iron-enriched segregation veinlet (F) lies directly on the trend of the Kilauea Iki rocks. However, the veinlet is distinctly poorer in alumina and richer in silica than Kilauea Iki sample 10, and lies well within the tholeiite field (Fig. 2). The similarity of Kilauea Iki sample 10 to typical alkalic basalts strongly suggests the possibility of derivation of the alkalic basalts in general from *undersaturated* tholeiitic magma.

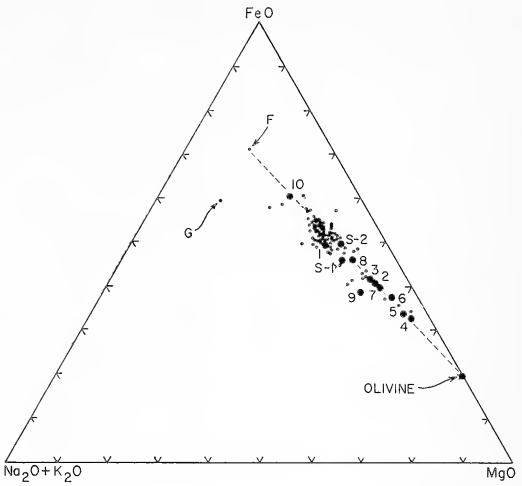

FIG. 1. Diagram of compositional variations in tholeiitic rocks of the Hawaiian Islands. Large dots represent the Kilauea Iki samples, the numbers corresponding with those in Table 1. Small dots represent other rocks. *F* represents the position of the iron-enriched segregation veinlet described by Kuno *et al.* (1957), and *G* indicates the position of the granophyre from Palolo Quarry, Honolulu, described by the same authors.

TABLE 1 (*Cont.*)

* Four careful determinations of each component in analysis 10 were made. The reproducibility (precision of measurement) is sufficient for the present purpose. Cu, Zn, V, Ba, Sr, Cr, Mo, W, and Pb were detected qualitatively by means of X-ray, but not in significant amounts, and cannot therefore be responsible for the low total in this analysis. The latter is the result of an appreciable amount of graphite in the analyzed sample, which was not soluble in mixed solutions of H_2SO_4 and HF or HNO_3 and HF. The graphite unquestionably came from the powdered graphite used to lubricate the joints of the drilling tools. The amounts of F, Cl, and C are being determined at the Tokyo Institute of Technology.

TABLE 2

COMPOSITIONS OF MATERIAL OBTAINED BY CALCULATION, ASSUMING VARIOUS AMOUNTS OF OLIVINE ADDED TO A PARENT MAGMA OF THE COMPOSITION OF THE PELE'S HAIR, COMPARED WITH COMPOSITIONS OBTAINED BY ACTUAL ANALYSIS OF KILAUEA IKI DRILL-HOLE SAMPLES

	SAMPLE 2		SAMPLE 3		SAMPLE 4		SAMPLE 5		SAMPLE 6		SAMPLE 7		SAMPLE 8		SAMPLE 9	
	Anal.	Calc.	Anal.	Calc.	Anal.	Calc.	Anal.	Calc.	Anal.	Calc.	Anal.	Calc.	Anal.	Calc.	Anal.	Calc.
SiO_2	46.8	47.4	47.0	47.5	44.6	45.1	45.6	45.5	45.6	46.4	47.2	47.1	48.3	48.3	48.4	48.8
Al_2O_3	12.0	11.5	12.1	11.6	9.3	8.6	9.1	9.0	10.6	10.3	11.1	11.2	12.9	12.6	13.0	13.4
CaO	9.9	9.6	9.9	9.7	7.2	7.0	7.8	7.6	8.4	8.5	9.6	9.4	10.4	10.6	10.0	11.3
Na_2O	1.8	1.9	1.8	1.9	1.4	1.4	1.2	1.5	1.5	1.7	1.5	1.9	2.0	2.1	2.1	2.3
K_2O	.4	.5	.5	.5	.3	.4	.3	.4	.4	.4	.4	.5	.5	.6	.6	.6
TiO_2	2.3	2.4	2.2	2.4	1.7	1.7	1.8	1.9	2.1	2.1	2.2	2.3	2.5	2.6	3.0	2.8
P_2O_5	.24	.20	.25	.21	.19	.15	.16	.16	.25	.18	.15	.20	.28	.23	.32	.24
Amount of olivine added (wt. per cent)	15		14		38		33		25		17		6		—1	

DIFFERENTIATION IN KILAUEA IKI LAVA

In Figure 1 the analyses of samples of Kilauea Iki lava are plotted on a standard AFM diagram, together with those of 85 other tholeiitic rocks of the Hawaiian Islands. The general tholeiitic trend of the Kilauea Iki samples is apparent.

The trends of both the Kilauea Iki rocks and of the tholeiitic rocks in general head directly toward the position of olivine (Fo_{80}) on the FeO-MgO join, and it is clear that compositional variations in the suite as a whole, including the Kilauea Iki rocks, can be accounted for largely by variations in the amount of olivine subtracted from, or added to, a parent magma with a composition lying along the same trend line.

Although movement of olivine was the main control in the differentiation, calculations indicate that minor amounts of other material also are involved. Column 2 of Table 3 shows the composition of the least amount of material that must be added to magma of the composition of the Pele's hair (Table 1, column 1) to produce a rock of the composition of the picrite-basalt from a depth of 7.5 ft. in the drill hole (Table 1, column 4). The material is preponderantly olivine, but includes also calcic plagioclase, pyroxene, and iron ore. The fact that the plagioclase is wholly anorthite indicates that some amount of material greater than the least possible actually has been added, since the first plagioclase to separate from a magma of the composition of the Pele's hair would have a more sodic composition (about An_{85}). The pyroxene also would be slightly poorer in Ca and increased in amount, but olivine would remain by far the most abundant component. Similar conclusions have been reached by Muir and Tilley (1957) regarding the 1840 picrite-basalt of Kilauea.

Similar results can be obtained by assuming a liquid phase of constant chemical composition like that of the Pele's hair and adding to it arbitrary amounts of olivine of the composition of that in the picrite-basalt (Table 1, analysis 11). Table 2 shows the results of these calculations compared to the actual compositions determined by analysis. The lower line indicates the amount of olivine added in each case, calculated on the basis of the amount of MgO and FeO in both the olivine and the Pele's hair. Since this method of calculation of necessity results in identical values of FeO and MgO in the analyzed and calculated materials, the figures are insignificant in the present connection and are omitted from the table. Note that for the most part the calculated compositions are quite close to the actual ones, again indicating that the principal substance added during the differentiation was olivine. In the case of sample 9 the agreement is somewhat less good, especially in the CaO content, suggesting that other factors than the addition of olivine have been involved. It is impossible to calculate sample 10 on the same basis, because the amount of olivine becomes negative—that is, olivine must be removed from, not added to, the Pele's hair to yield sample 10.

The composition of the liquid phase of the magma during the beginning of the eruption is represented by the analysis of Pele's hair (Table 1, column 1). However, even at that time the bulk composition of the magma was somewhat more mafic, due to the presence of olivine phenocrysts and possibly other crystals not contained in the analyzed sample. This bulk composition is probably better represented by analyses S-1 or S-2. These in turn are less mafic than the average magma extruded later in the eruption. Richter and Eaton (1960) note a general tendency for the lava of late stages to be a little more mafic than that of the early stages. The best approximation to the composition of the "parent magma" for the suite of drill-hole samples may therefore be an average of analyses 2 and 3. This average is given in column 1 of Table 3.

Whereas samples 4 to 7 are probably cumulative types, derived by addition to the parent magma of sinking crystals, largely olivine, samples 8 to 10 are probably residual magma from which crystals have been removed. In Figure 1 they lie along the same trend, but on the other side of the parent magma (samples 2 and 3) from the cumulative types. Their position on the same trend line suggests that they have been derived largely by the same general process as the other Kilauea Iki rocks and the tholeiitic rocks in general. However, in Figure 2 samples 9 and 10 lie along a line that deviates markedly from the general tholeiitic trend. Sample 10 in

TABLE 3

PROBABLE PARENT MAGMA AND MATERIAL ADDED TO OR SUBTRACTED FROM IT TO OBTAIN OTHER ROCKS

	1	2	3	4	5	6	7	8
SiO_2	46.9	40.6	51.4	49.2	49.0	45.4	45.1	40.5
Al_2O_3	12.9	5.0	9.1	12.9	13.2	10.7	9.2	8.0
Fe_2O_3	2.1	0.9	2.5	1.8	1.7	2.8	3.8	3.5
FeO	9.6	11.7	1.7	8.8	9.6	6.0	6.4	8.0
MgO	14.6	38.1	15.7	10.0	9.3	22.7	22.6	30.5
CaO	9.9	3.1	17.7	12.2	11.6	11.1	11.1	7.5
Na_2O	1.5	0.0	2.0	2.2	2.2	0.7	0.7	0.0
K_2O	0.4	0.0	0.0	0.5	0.6	0.0	0.0	0.0
TiO_2	2.3	0.6	0.0	2.3	2.6	0.6	0.6	1.5
NORMS								
ne	.....	.....	2.6	.....	.....	.....	.....	.....
or	2.2	.....	.....	2.8	3.3	.....	.....	.....
ab	12.6	.....	12.0	19.5	18.3	5.8	5.8	.....
an	27.2	13.6	15.8	23.9	24.5	26.1	22.0	21.7
di wo	8.8	0.7	30.0	15.0	13.5	12.1	13.5	6.5
di en	6.1	0.5	25.4	9.7	8.4	9.5	10.4	5.1
di fs	2.0	0.1	0.7	4.2	4.2	1.2	1.6	0.7
hy en	11.9	2.9	.....	7.0	8.5	5.9	7.5	3.5
hy fs	4.0	0.7	.....	3.2	4.4	0.8	1.1	0.4
ol fo	13.0	64.3	13.8	5.8	4.4	29.3	27.0	47.3
ol fa	5.0	14.5	0.4	3.0	2.8	4.3	4.1	6.3
mt	3.0	1.4	3.7	2.6	2.6	4.2	5.6	5.1
il	4.4	1.2	.....	4.4	5.0	1.2	1.2	2.9
plagioclase	An_{68}	.....	An_{57}	An_{55}	An_{57}	An_{82}	An_{79}	.....
Per cent wo in pyroxene	27	.....	53	38	35	41	39	40
Per cent of crystallization	.....	.....	50	75	90	25	50	17

1. Average of analyses 2 and 3, Table 1.
2. Least amount of material that added to Pele's hair (Table 1, analysis 1) yields the picrite-basalt (Table 1, analysis 4).
3. Least amount of material that subtracted from Pele's hair yields the composition of sample 10 (Table 1).
4. Material that subtracted from Pele's hair yields sample 10, assuming 75 per cent crystallization.
5. Material that subtracted from Pele's hair yields sample 10, assuming 90 per cent crystallization.
6. Least amount of material that subtracted from column 1 of this table yields sample 10.
7. Material that subtracted from column 1 yields sample 10, assuming 50 per cent crystallization.
8. Least amount of material that subtracted from column 1 yields sample 8 (Table 1).

particular differs greatly in alkali: silica ratio from typical tholeiitic rocks, containing half again as much alkali as rocks with the same silica content lying on the main trend line, such as sample 8.

If we assume that the liquid phase of the parent magma had the composition of the Pele's hair (Table 1, analysis 1), the composition of the material that must be removed from it by crystallization to yield magma of the composition of sample 10 can be calculated. Columns 3, 4, and 5 of Table 3 indicate the composition of the material, assuming respectively 50, 75, and 90 per cent crystallization of the parent liquid.

Column 3 appears to represent an impossible situation, because the plagioclase is considerably richer in sodium (Ab_{43}) than it should be (Ab_{30}) to have separated from the parent magma at that degree of crystallization. The same objection applies in lesser degree to

columns 4 and 5. Furthermore, if the conclusion that the pool of lava beneath the crust was largely liquid at the end of the eruption is correct, the thinness of the solid crust (less than 20 ft.) seems incompatible with degrees of crystallization of 90 or even 75 per cent. Also, in column 3 the pyroxene is considerably more calcic than would be expected to crystallize from a magma of the composition of the Pele's hair.

Columns 6 and 7 of Table 3 show the composition of material that would have to be separated from a parent magma of the average composition of analyses 2 and 3 (Table 1) to yield magma of the composition of sample 10, assuming about 25 and 50 per cent crystallization respectively. The mineral compositions indicated in the norms appear quite reasonable to have crystallized from magma of that composition. This appears to furnish further corroboration that samples 2 and 3 more nearly represent the parent magma of the drill-hole samples, and to indicate that sample 10 could have been derived from that parent wholly by crystal differentiation.

In Figure 2, as in Figure 1, samples 2 to 8 lie along a trend controlled largely by movement of olivine. The sharp divergence of samples 9 and 10 from that trend can be explained largely by the onset of more abundant crystallization of pyroxene. The position of the average tholeiitic pyroxene given by Kuno (1960: 128) is plotted on the lower boundary of Figure 2, and it will be seen that a trend line from sample 8 through samples 9 and 10 intersects the silica scale close to the pyroxene point. It will also be noted that the norms of columns 6 and 7 (Table 3) contain considerably more pyroxene than does that of column 8, which represents the material that must be separated from the same parent magma to yield sample 8. The derivation of the alkali-rich sample 10 by increased crystallization of pyroxene agrees with Murata's (1960) suggestion that crystallization of pyroxene is an important factor in the formation of the alkalic basalts.

Thus, it appears possible to derive all of the Kilauea Iki rocks by crystallization differentiation, and unquestionably this process has been of prime importance. This does not, however, prove that no other process has been involved.

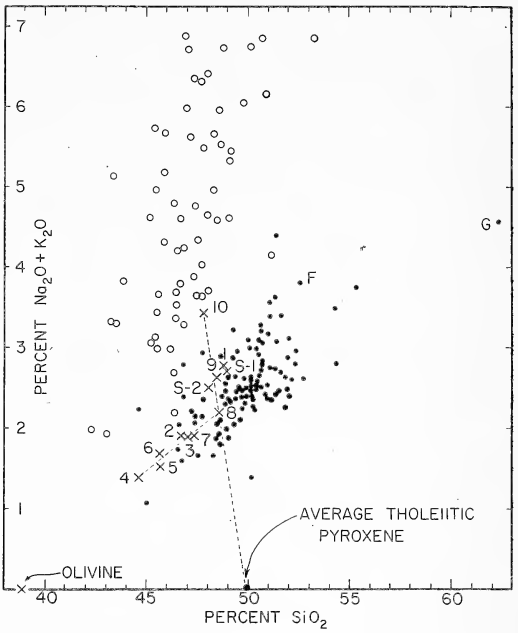

FIG. 2. Alkali : silica diagram of Hawaiian lavas. The compositions of the lavas of the 1959 eruption of Kilauea Iki are shown by crosses, those of rocks belonging to the tholeiitic suite by solid dots, and those of rocks of the alkalic suite by open circles. The point for olivine represents phenocrysts of that mineral in the 1959 lava; that for pyroxene is an average of tholeiitic pyroxenes listed by Kuno (1960: 128). The dashed line indicates the trend of differentiation of the Kilauea Iki drill-hole samples. *F* indicates the position of the iron-enriched segregation veinlet of Kilauea, and *G* that of the granophyre from Palolo Quarry (Kuno *et al.*, 1957).

Indeed, it would seem to be a foregone conclusion that other processes must have been going on in the magma and must have, to some degree, affected the composition of the magma. Such effects are most likely to have been appreciable in the rocks that depart from the main trend of differentiation, such as samples 9 and 10. The departure of these samples from the trend results principally from their greater richness in alkalies. The transfer and concentration of alkalies in one way or another as a part of magmatic differentiation has been suggested by many writers. It has thus far proved difficult to demonstrate to the satisfaction of petrologists in general, but this does not seem an adequate reason to omit it from consideration.

One of the suggested mechanisms by which alkalies may be concentrated is volatile transfer —volatile compounds moving upward toward points of gas escape, carrying alkalies in solution and releasing them because of pressure decrease at and near the top of the magma body. Another process is thermodiffusion, by which certain substances, including alkalies, migrate toward cooling surfaces (Wahl, 1946). Either or both of these may well have operated to some degree in the Kilauea Iki lava pool. Small amounts of gas have oozed from the surface of the pool constantly, ever since its formation. Likewise, the broad crusted surface of the pool exposed directly to the atmosphere and cooled by wind and frequent rains provides an ideal condition for the operation of thermodiffusion. These processes may be bringing about a gradual enrichment of the upper part of the liquid magma in alkalies. Further sampling of the congealing lava pool is highly desirable, to determine whether the trend observed in sample 10 is a continuing one.

Whether the divergence of Kilauea Iki sample 10 from the general tholeiitic trend offers a clue to the origin of the alkalic basalts cannot now be asserted. It is noteworthy, however, that it is closely similar to the transverse trend found by Tomkeieff (1937) in the Paleozoic basalts of Scotland.

CONCLUSIONS

The foregoing evidence: (1) Indicates the existence in Hawaii of completely liquid tholeiitic magma undersaturated in silica at least to the degree of containing nearly 10 per cent normative olivine; (2) confirms the dominance in the tholeiitic suite of crystal differentiation involving primarily the movement of magnesian olivine, with small amounts of pyroxene and calcic plagioclase; (3) indicates that at least marginal members of the alkalic suite can be derived from undersaturated tholeiitic magma; (4) suggests that this can be accomplished by crystallization differentiation controlled by the separation of pyroxene; but (5) leaves open the possibility of the operation of such other processes of differentiation as volatile transfer of alkalies and thermodiffusion.

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A Guide to the Literature and Distributions of Pacific Benthic Algae from Alaska to the Galapagos Islands

E. Yale Dawson[1]

Fifteen years ago the writer prepared the first "Guide to the marine algae of Pacific North America" (Dawson, 1946*a*). That first check list of the benthic flora of the region has become outdated by the results of extensive explorations of the Mexican coasts and islands from 1946 to 1952, and, subsequently, of the coasts of Central America and British Columbia. Doty's "Marine algae of Oregon" (1947) appeared as the first treatment of that region, and a number of studies of California algae have added considerable literature for that area. The fuller knowledge of the Mexican and Central American algae has shown such affinities with the flora of the Galapagos Archipelago that it has seemed appropriate to include the entire northeast Pacific in the present list, from the southern boundary of Ecuador and the Galapagos Islands to the Aleutian Islands, and including Clipperton Island and the Revillagigedo Archipelago, but not extending as far west as Hawaii or the Line Islands, for which an independent account is intended.

As before, the literature cited represents the references that provide an adequate key to all previous literature dealing with the occurrence of a given species along the Pacific American coasts. Thus, some 80 titles have been added to bring this expanded list up to date, but one will find himself frequently referred to larger bibliographies such as those of Smith (1944), Taylor (1945), Scagel (1957), Dawson (1954*a*), and others, for earlier or more exhaustive citations of literature.

For the sake of consistency, the distribution records are cited from north to south.

The classification is essentially according to that of Papenfuss (1955).

[1] Beaudette Foundation for Biological Research, Solvang, California. Manuscript received May 16, 1960.

Systematic List

Phylum CHLOROPHYCOPHYTA

Order VOLVOCALES

Suborder VOLVOCINEAE

Fam. POLYBLEPHARIDACEAE

Stephanoptera gracilis (Artari) G. M. Smith

Scagel, 1957
Northern Wash. to Monterey, Calif.

Dunaliella salina (Dunal) Teodoresco

Scagel, 1957
Northern Wash. to Monterey, Calif.

Fam. CHLAMYDOMONADACEAE

Platymonas subcordiformis (Wille) Hazen

Smith, 1944
Monterey, Calif.

Suborder CHLORODENDRINEAE

Fam. CHLORANGIACEAE

Collinsiella tuberculata Setchell & Gardner

Scagel, 1957
Southern British Columbia to Pacific Grove, Calif.

Prasinocladus ascus Proskauer

Proskauer, 1950
Near Santa Cruz, Calif.

Prasinocladus lubricus Kuckuck

Proskauer, 1950; Scagel, 1957
Friday Harbor, Wash., to Monterey, Calif.

ORDER **ULOTRICHALES**

FAM. ULOTRICHACEAE

Ulothrix flacca (Dillwyn) Thuret, in Le Jolis

Scagel, 1957
St. Michael, Alaska, to Calif.

Ulothrix implexa Kützing

Scagel, 1957
Bering Sea to Monterey, Calif.

Ulothrix laetevirens (Kützing) Collins

Scagel, 1957
Unalaska, Alaska, to Calif.

Ulothrix pseudoflacca f. *minor* Wille

Setchell & Gardner, 1920
Sitka, Alaska

Ulothrix pseudoflacca f. *major* Wille

Setchell & Gardner, 1920
San Francisco, Calif.

Ulothrix pseudoflacca f. *maxima* Setchell & Gardner

Setchell & Gardner, 1920
San Francisco, Calif.

Ulothrix zonata (Weber & Mohr) Kützing

Doty, 1947
Harris State Park; Squaw Creek, Oreg.

Hormidium rivulare Kützing

Doty, 1947
Winchester Bay, Oreg.

FAM. CHAETOPHORACEAE

Bolbocoleon piliferem Pringsheim

Setchell & Gardner, 1920; Dawson, 1945*b*
Southern Calif.

Pilinia lunatiae f. *simplex* Thivy

Taylor, 1945
Panama City, Panama

Pilinia maritima f. *pacifica* Thivy

Taylor, 1945; Dawson, 1954
Isla Clarión, Revillagigedo Arch.; Galapagos Arch.

Phaeophila dendroides (Crouan) Batters

Dawson, 1954
Isla María Magdalena, Nayarit

Phaeophila engleri Reinke

Taylor, 1945; Dawson, 1954
Isla Clarión, Revillagigedo Arch., to Isla Taboga, Panamá; Galapagos Arch.

Phaeophila polymorpha Jao

Scagel, 1957
Northern Wash.

Ectochaete perforans Thivy

Taylor, 1945
Galapagos Arch.

Zygomitus reticulatus Bornet & Flahault

Taylor, 1945
Galapagos Arch.

Entocladia cingens Setchell & Gardner

Setchell & Gardner, 1920
San Diego, Calif.

Entocladia codicola Setchell & Gardner

Smith, 1944; Dawson, 1945*b*
Monterey Peninsula to La Jolla, Calif.

Entocladia condensata Setchell & Gardner

Dawson, 1954
Puerto Libertad; Isla San Esteban, Gulf of Calif.

Entocladia mexicana Setchell & Gardner

Dawson, 1954
Isla Ángel de la Guarda; La Paz, Gulf of Calif.

Entocladia polysiphoniae Setchell & Gardner

Dawson, 1954; Dawson, 1957 (as probably identical with *E. viridis*)
Guaymas; La Paz, Gulf of Calif.

Entocladia viridis Reinke

Scagel, 1957; Dawson, 1957
Southern British Columbia to Monterey, Calif.; Galapagos Arch.

Endophyton ramosum Gardner

Doty, 1947
Brookings, Oreg., to Monterey Peninsula, Calif.

Pseudodictyon geniculatum Gardner

Doty, 1947
Sunset Bay, Oreg., to Pacific Grove, Calif.

Internoretia freyeana Setchell & Gardner

Scagel, 1957
Friday Harbor, Wash.

Ulvella setchellii Dangeard

Smith, 1944; Hollenberg, 1948; Dawson, 1954
Pacific Grove, Calif., to Isla Guadalupe, Baja Calif.

Pseudulvella applanata Setchell & Gardner

Smith, 1944
Carmel, Calif.

Pseudulvella consociata Setchell & Gardner

Doty, 1947
South Bay, Oreg.; Alameda, Calif.

Pseudulvella prostrata (Gardner) Setchell & Gardner

Setchell & Gardner, 1920
San Francisco, Calif.

Pseudopringsheimia apiculata Setchell & Gardner

Smith, 1944
San Francisco; Monterey, Calif.

Pringsheimiella marchantae (Setchell & Gardner) Schmidt

Schmidt, 1935; Dawson, 1954
La Paz, Baja Calif.

Pringsheimiella scutata (Reinke) Schmidt & Petrack, in Schmidt

Dawson, 1960*a*
Isla Guadalupe, Baja Calif.

FAM. TRENTEPOHLIACEAE

Trentepholia odorata var. *umbrina* (Kützing) Hariot

Setchell & Gardner, 1920
San Pedro, Calif.

FAM. MONOSTROMACEAE

Monostroma areolatum Setchell & Gardner

Setchell & Gardner, 1920
Sitka, Alaska

Monostroma dactyliferum Taylor

Taylor, 1945
Guayas, Ecuador

Monostroma ecuadoreanum Taylor

Taylor, 1945; Dawson, 1957*b*
Golfo Dulce, Costa Rica?; Guayas, Ecuador

Monostroma fractum Jao

Scagel, 1957
Turn I., Wash.

Monostroma fuscum (Postels & Ruprecht) Wittrock var. *fuscum*

Scagel, 1957
Kukak Bay, Alaska, to northern Wash.

Monostroma fuscum var. *blyttii* (Areschoug) Collins

Scagel, 1957
Southern British Columbia to northern Wash.

Monostroma fuscum var. *splendens* (Ruprecht) Rosenvinge

Scagel, 1957
St. Paul I., Alaska, to southern British Columbia

Monostroma grevillei (Thuret) Wittrock var. *grevillei*

Setchell & Gardner, 1920
Unalaska, Alaska

Monostroma grevillei var. *lubricum* (Kjellman) Collins

Setchell & Gardner, 1920
Sitka, Alaska

Monostroma grevillei var. *vahlii* (J. Agardh) Rosenvinge

Setchell & Gardner, 1920; Okamura, 1933
Aleutian Islands to Sitka, Alaska

Monostroma orbiculatum Thuret

Setchell & Gardner, 1920
Central Calif.

Monostroma oxyspermum (Kützing) Doty

Scagel, 1957
Southern British Columbia to southern Calif.

Monostroma zostericola Tilden

Scagel, 1957
Southern British Columbia to Monterey, Calif.

Blidingia minima (Nägeli) Kylin var. *minima*

Scagel, 1957; Dawson, 1959*c* (as *Enteromorpha minima*)
Dutch Harbor, Alaska, to Mexico

Blidingia minima var. *subsalsa* (Kjellman) Scagel

Scagel, 1957
Skagway, Alaska, to Chetco Cove, Oreg.

FAM. ULVACEAE

Enteromorpha acanthophora Kützing

Dawson, 1949*a*, 1954; Dawson, Neushul, Wildman, 1960*a*
Bahía Tortuga, Baja Calif.; Gulf of Calif.

Enteromorpha ahlneriana Bliding

Doty, 1947
North Bend, Oreg.

Enteromorpha clathrata (Roth) Greville

Dawson, 1954 (as *E. plumosa*); Scagel, 1957; Dawson, 1959, 1959*b*
Valdez, Alaska, to Carmel, Calif.; Isla Clarión, Revillagigedo Arch.; southern Gulf of Calif.; Clipperton I.

Enteromorpha compressa (Linnaeus) Greville

Dawson, 1949*a*, 1954; Scagel, 1957; Dawson, 1957*b*, 1959, 1959*c*
Bering Sea to Costa Rica

Enteromorpha crinita (Roth) J. Agardh

Taylor, 1945; Dawson, 1959*c*
Valdes, Alaska, to San Diego, Calif.; Galapagos Arch.

Enteromorpha groenlandica (J. Agardh) Setchell & Gardner

Setchell & Gardner, 1920
Bering Sea to Unalaska, Alaska

Enteromorpha intestinalis (Linnaeus) Link f. *intestinalis*

Okamura, 1933; Scagel, 1957; Dawson, 1957*c*
Kukak Bay, Alaska, to La Paz, Baja Calif.; Gulf of Calif.

Enteromorpha intestinalis f. *cylindracea* J. Agardh

Scagel, 1957
Popof I., Alaska, to Mexico

Enteromorpha intestinalis f. *maxima* J. Agardh

Scagel, 1957
Kukak Bay, Alaska, to Mexico

Enteromorpha intestinalis f. *clavata* J. Agardh

Scagel, 1957
Kukak Bay, Alaska, to Mexico

Enteromorpha lingulata J. Agardh

Dawson, 1954, 1957*b*; Taylor, 1945
Isla Guadalupe, Baja Calif., to Balboa, Canal Zone; Galapagos Arch.

Enteromorpha linza (Linnaeus) J. Agardh

Dawson, 1954; Scagel, 1957; Dawson, 1959*c* (as *Ulva linza*)
Orca, Alaska, to Mexico

Enteromorpha marginata J. Agardh

Scagel, 1957
Vancouver I., British Columbia, to Calif.

Enteromorpha prolifera (Müller) J. Agardh var. *prolifera*

Dawson, 1954; Scagel, 1957
Golovnin Bay, Alaska, to Central America

Enteromorpha prolifera var. *flexuosa* (Wulfen) Doty

Doty, 1947; Setchell & Gardner, 1920 (as *E. flexuosa*); Taylor, 1945 (as *E. flexuosa*)
Santa Barbara, Calif., to Puerto Parker, Costa Rica; Guayas, Ecuador

Enteromorpha salina var. *polyclados* Kützing

Taylor, 1945
San Franciso Bay, Calif.; Galapagos Arch.

Enteromorpha torta (Mertens) Reinbold

Scagel, 1957
Southern British Columbia and Wash.; San Diego, Calif.

Enteromorpha tubulosa (Kützing) Kützing

Taylor, 1945; Dawson, 1954; Scagel, 1957
Northern Wash. to Cabo Colnett, Baja Calif.; Galapagos Arch.

Ulva angusta Setchell & Gardner

Smith, 1944; Dawson, 1954 (as *U. taeniata* and as *Enteromorpha angusta*), 1959*c*; Doty, 1947 (as *Enteromorpha angusta*)
Oreg. to southern Calif.; Isla Guadalupe, Baja Calif.?; Guaymas, Sonora

Ulva californica Wille

Doty, 1947; Dawson, 1959*c*, 1960*a*
Oreg.; Moss Beach, Calif.; southern Calif.; Isla Magdalena, Baja Calif.

Ulva dactylifera Setchell & Gardner

Taylor, 1945; Dawson, 1954, 1959
Southern Calif. to San Roque, Baja Calif.; southern Gulf of Calif.; Guayas, Ecuador ?; Galapagos Arch.?

Ulva expansa (Setchell) Setchell & Gardner

Dawson, 1954; Scagel, 1957
Southern British Columbia to Monterey, Calif.; La Paz, Baja Calif.?

Ulva fasciata Delile

Farlow, 1902; Taylor, 1945
Galapagos Arch.

Ulva fenestrata Postels & Ruprecht

Scagel, 1957
Sitka, Alaska, to Oreg.

Ulva lactuca Linnaeus

Taylor, 1945; Dawson, 1954; Scagel, 1957; Dawson, 1959, 1959*c*
Bering Sea to Guayas, Ecuador; Galapagos Arch.

Ulva latissima Linnaeus

Scagel, 1957
Juneau, Alaska, to northern Wash.

Ulva lobata (Kützing) Setchell & Gardner

Taylor, 1945; Doty, 1947; Dawson, 1954, 1957, 1959*b*, 1959*c*
Oreg. to San Diego, Calif.; Bahía Petatlán, Guerrero; Clipperton I.; Guayas, Ecuador; Galapagos Arch.

Ulva rigida C. Agardh

Dawson, 1949*a*; Scagel, 1957; Dawson, 1954, 1959*c*
Uyak Bay, Alaska, to La Paz, Baja Calif.; Gulf of Calif.

Ulva spinulosa Okamura & Segawa

Dawson, 1960*a*
Puerto Guatulco, Oaxaca

Ulva stenophylla Setchell & Gardner

Doty, 1947
Chetco Cove, Oreg. to Big Sur, Calif.

Ulva taeniata (Setchell) Setchell & Gardner

Doty, 1947; Dawson, 1954, 1959*c*
Coos Bay, Oreg., to Point Conception, Calif. (more southern records are probably all *U. angusta*)

Ulva vexata Setchell & Gardner

Doty, 1947 (as *Enteromorpha vexata*)
Oreg.; San Francisco, Calif.

Percursaria percursa (C. Agardh) Rosenvinge
Scagel, 1957
Amaknak I., Alaska, to San Francisco Bay, Calif.

ORDER **SCHIZOGONIALES**

FAM. PRASIOLACEAE

Schizogonium murale f. *uniseriatum* Jao
Scagel, 1957
Dinner Point, Wash.

Prasiola borealis Reed
Setchell & Gardner, 1920
Unalaska, Kodiak, and Baranof islands, Alaska

Prasiola calophylla (Carmichael) Meneghini
Scagel, 1957
Whidbey I., Wash.

Prasiola delicatula Setchell & Gardner
Setchell & Gardner, 1920
Sitka, Alaska

Prasiola linearis Jao
Scagel, 1957
Argyle Lagoon, Wash.

Prasiola meridionalis Setchell & Gardner
Scagel, 1957; Silva, 1957
Friday Harbor, Wash., to Carmel, Calif.; Santa Cruz I., Calif.

Rosenvingiella constricta (Setchell & Gardner) Silva
Silva, 1957; Scagel, 1957
Friday Harbor, Wash.; Tomales Point; Monterey; Santa Cruz I., Calif.

Rosenvingiella polyrhiza (Rosenvinge) Silva
Silva, 1957
Amaknak I., Alaska

ORDER **CHLOROCOCCALES**

FAM. CHLOROCOCCACEAE

Chlorochytrium inclusum Kjellman
Scagel, 1957
Sitka, Alaska, to Camel, Calif.

Chlorochytrium porphyrae Setchell & Gardner
Scagel, 1957
Cape Flattery, Wash.; San Francisco; Monterey Peninsula, Calif.

Chlorochytrium schmitzii Rosenvinge
Setchell & Gardner, 1920
Kodiak I., Alaska

Codiolum penicilliforme (Roth) Silva
Scagel, 1957 (as *Codiolum gregarium*); Silva, 1957*a* (as the sporophyte generation of *Urospora penicilliformis*)
Southern British Columbia to northern Wash.

Codiolum petrocelidis Kuckuck
Scagel, 1957; Fan, 1959 (Fan, and also Hollenberg, 1958, indicate this as the sporophyte generation of *Spongomorpha coalita*)
Northern Wash. to Monterey, Calif.

Codiolum pusillum f. *subsessile* Jao
Scagel, 1957
Brown I., Wash.

FAM. GOMONTIACEAE

Gomontia polyrhiza (Lagerheim) Bornet & Flahault
Scagel, 1957
Neah Bay, Wash., to Monterey, Calif.

ORDER **CLADOPHORALES**

FAM. CLADOPHORACEAE

Rhizoclonium crassipellitum var. *robustum* G. S. West
Taylor, 1945
Galapagos Arch.

Rhizoclonium implexum (Dillwyn) Kützing
Taylor, 1945 (as *R. riparium* var. *implexum*); Scagel, 1957
St. Michael I., Alaska, to Carmel, Calif.; Galapagos Arch.

Rhizoclonium kerneri Stockmayer
Dawson, 1959; Scagel, 1957
Victoria, British Columbia

Rhizoclonium kochianum Kützing

Taylor, 1945 (as *R. kerneri*); Dawson, 1959, 1960*a*
Puerto Escondido, Gulf of Calif.; Isla Clarión, Revillagigedo Arch.; Isla Jicarón, Panamá

Rhizoclonium rhizophilum Taylor

Taylor, 1945
Galapagos Arch.

Rhizoclonium riparium (Roth) Harvey

Scagel, 1957
Unalaska, Alaska, to southern Calif.; Galapagos Arch.

Rhizoclonium tortuosum (Dillwyn) Kützing

Scagel, 1957
Kodiak Bay, Alaska, to Carmel, Calif.

Lola lubrica (Setchell & Gardner) A. & G. Hamel

Dawson, 1954; Scagel, 1957
Northern Wash. to Puerto Culebra, Costa Rica

Urospora doliifera (Setchell & Gardner) Doty

Doty, 1947
Chetco Cove, Oreg.; San Francisco, Calif.

Urospora grandis Kylin

Scagel, 1957
Unalaska, Alaska, to Oreg.

Urospora penicilliformis (Roth) Areschoug

Dawson, 1949 (as *Chaetomorpha catalinae*); Dawson, 1954*d*; Scagel, 1957; Silva (1957*a*) treats this as *Codiolum penicilliformis*, the alternate, gametophyte generation of *Codiolum gregarium*
Bering Sea to southern Calif.

Urospora sphaerulifera (Setchell & Gardner) Scagel

Scagel, 1957
Whidbey I., Wash.

Urospora tetraciliata (Frye & Zeller) Scagel

Scagel, 1957
San Juan County, Wash.

Urospora vancouveriana (Tilden) Scagel

Scagel, 1957
Oak Bay, Vancouver I., British Columbia

Urospora wormskioldii (Mertens) Rosenvinge

Scagel, 1957
Southern British Columbia to Gualala, Calif.

Chaetomorpha aerea (Dillwyn) Kützing

Dawson, 1954, 1959*c*
Santa Cruz to San Diego, Calif.; northern Gulf of Calif.

Chaetomorpha antennina (Bory) Kützing

Dawson, 1945*b*, 1954, 1954*c*, 1959, 1959*b*; Dawson & Beaudette, 1960
La Jolla, Calif., to Guayas, Ecuador; Clipperton I.; Galapagos Arch.

Chaetomorpha atrovirens Taylor, approx.

Dawson, 1954
Isla Guadalupe

Chaetomorpha bangioides Dawson

Dawson, 1954, 1959
Isla Patos; Puerto Escondido, Gulf of Calif.

Chaetomorpha brachygona var. *crassipellita* Taylor

Taylor, 1945
Galapagos Arch.

Chaetomorpha californica Collins

Setchell & Gardner, 1920
Laguna Beach to La Jolla, Calif.

Chaetomorpha cannabina (Areschoug) Kjellman

Scagel, 1957
Norton Sound, Alaska, to Puget Sound, Wash.

Chaetomorpha clavata (C. Agardh) Kützing

Dawson, 1954
Punta Descanso; Cabo Colnett, Baja Calif.

Chaetomorpha crassa (C. Agardh) Kützing

Dawson, 1954
Islas San Benitos; Bahía Magdalena, Baja Calif.

Chaetomorpha exposita (Børgesen) Dawson

Dawson, 1954*c*
Isla San Benedicto, Revillagigedo Arch.

Chaetomorpha gracilis Kützing

Dawson, 1954*c*
Isla San Benedicto, Revillagigedo Arch.

Chaetomorpha indica Kützing

Dawson, 1960*a*
Isla del Rey, Panamá

Chaetomorpha linoides (C. Agardh) Kützing

Dawson, 1954
Cabo San Lucas, Baja Calif.; Mazatlán, Sinaloa

Chaetomorpha linum (Müller) Kützing

Dawson, 1954; Taylor, 1945; Dawson, 1959
Isla Cedros, Baja Calif.; Isla Carmén, Gulf of Calif.; Galapagos Arch.

Chaetomorpha melagonium (Weber & Mohr) Kützing

Setchell & Gardner, 1920; Okamura, 1933
Aleutian Islands to Kodiak I., Alaska

Chaetomorpha pachynema Montagne

Dawson, 1954
Punta Palmilla, Baja Calif.

Chaetomorpha tenuissima Jao

Scagel, 1957
Northern Wash.

Chaetomorpha torta (Farlow) McClatchie

Setchell & Gardner, 1920; Dawson, 1945*b*, 1949*a*, 1954, 1959*c*; Dawson, Neushul, Wildman, 1960
Southern Calif. to Isla Magdalena, Baja Calif.

Cladophora albida (Hudson) Kützing

Scagel, 1957; Dawson, 1954, 1959, 1960*a*
Southern British Columbia to northern Wash.; San Pedro, Calif.; Gulf of Calif.; Isla Grande, Guerrero

Cladophora amphibia Collins

Setchell & Gardner, 1920
San Francisco Bay, Calif.

Cladophora bertolonii var. *hamosa* (Kützing) Ardissone

Smith, 1944
Pacific Grove, Calif.

Cladophora crystallina (Roth) Kützing

Dawson, 1960*a*
Bahía Culebra, Costa Rica

Cladophora delicatula Montagne

Doty, 1947; Dawson, 1954
Oreg. to San Diego, Calif.; Rio Mayo, Sonora

Cladophora elmorei Dawson

Dawson, 1949
San Clemente Island, Calif.

Cladophora flexuosa (Griffiths) Harvey

Scagel, 1957
Annettee I., Alaska, to San Diego, Calif.

Cladophora glaucescens (Griffiths) Harvey

Scagel, 1957
Nanaimo, British Columbia, to Oakland, Calif.

Cladophora gracilis (Griffiths) Kützing f. *gracilis*

Scagel, 1957
Sitka, Alaska; Neah Bay, Wash.

Cladophora gracilis f. *expansa* Farlow

Dawson, 1954
Isla Clarión, Revillagigedo Arch.

Cladophora graminea Collins

Smith, 1944; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Santa Cruz, Calif., to Isla Magdalena, Baja Calif.; Guaymas, Sonora

Cladophora hemispherica Gardner

Doty, 1947; Smith, 1944; Dawson, 1959*c*
Oreg. to northern Los Angeles Co., Calif.

Cladophora hesperia Setchell & Gardner

Dawson, 1954, 1954*d*
Vicinity of Isla Cedros, Baja Calif.; Kino, Sonora, to Mazatlán, Sinaloa

Cladophora hutchinsiae (Dillwyn) Kützing var. *hutchinsiae*

Scagel, 1957
Vancouver I., British Columbia

Cladophora hutchinsiae var. *distans* (C. Agardh) Kützing

Scagel, 1957
Southern British Columbia

Cladophora inserta Dickie f.

Dawson, 1957
Isla San Benedicto, Revillagigedo Arch.

Cladophora laetevirens (Dillwyn) Kützing

Scagel, 1957
Vancouver, British Columbia, and Straits of Juan de Fuca, Wash.

Cladophora macdougalii Howe

Dawson, 1954
Bahía San Felipe, Gulf of Calif.

Cladophora magdalenae Harvey

Dawson, 1954
Scammon Lagoon, Baja Calif.

Cladophora microcladioides Collins f. *microcladioides*

Dawson, 1954; Scagel, 1957; Dawson, 1959*c*
Southern British Columbia to Bahía Viscaino, Baja Calif.; Gulf of Calif.

Cladophora microcladioides f. *stricta* Collins

Setchell & Gardner, 1920
San Diego, Calif.

Cladophora ovoidea Kützing

Smith, 1944
Santa Cruz to Monterey, Calif.

Cladophora panamensis Taylor

Taylor, 1945
Bahía Honda, Panamá

Cladophora perpusilla Skottsberg & Levring

Dawson, 1954*c*, 1957, 1959*b*, 1960*a*
Isla San Benedicto, Revillagigedo Arch.; Puerto Guatulco, Oaxaca; Clipperton I.; Galapagos Arch.

Cladophora prolifera (Roth) Kützing

Taylor, 1945; Dawson, 1954, 1957*b*
Scammon Lagoon, Baja Calif.; Costa Rica; Guayas, Ecuador; Galapagos Arch.

Cladophora rudolphiana (C. Agardh) Kützing f. *rudolphiana*

Dawson, 1954, 1957*b*
Guaymas, Sonora; Golfo de Nicoya, Costa Rica

Cladophora rudolphiana f. *eramosa* Gardner

Setchell & Gardner, 1920; Dawson, 1954
San Francisco Bay, Calif.; Guaymas, Sonora

Cladophora socialis Kützing

Dawson, 1957*b*, 1959*b*
Golfo de Nicoya, Costa Rica; Clipperton I.

Cladophora stimpsonii Harvey

Scagel, 1957
Southern British Columbia to southern Calif.

Cladophora tiburonensis Dawson

Dawson, 1954
Isla Tiburón, Gulf of Calif.; Mazatlán, Sinaloa

Cladophora trichotoma (C. Agardh) Kützing f. *trichotoma*

Dawson, 1954; Scagel, 1957; Dawson, 1959*c*
Southern British Columbia to Isla Cedros, Baja Calif.; La Paz, Gulf of Calif. ?

Cladophora trichotoma f. *elongata* Collins

Setchell & Gardner, 1920
Point Carmel, Calif.

Cladophora utriculosa Kützing

Dawson, 1959, 1960*a*
Isla San Francisco, Gulf of Calif.; Bahía Chacahua, Oaxaca; Bahía Potrero Grande, Costa Rica

Spongomorpha arcta (Dillwyn) Kützing

Scagel, 1957
Bering Sea to Puget Sound, Wash.

Spongomorpha coalita (Ruprecht) Collins

Scagel, 1957; Fan, 1959 (Note: Hollenberg, 1958, and Fan, 1959, show this to be the gametophyte generation of *Codiolum petrocelidis*)
Unalaska, Alaska, to Carmel, Calif.

Spongomorpha conjuncta Taylor

Taylor, 1945
Galapagos Arch.

Spongomorpha duriuscula (Ruprecht) Collins

Okamura, 1933; Doty, 1947
Aleutian Islands to Karluk, Alaska; Oreg.

Spongomorpha hystrix Stroemfelt

Setchell & Gardner, 1920; Okamura, 1933
Agattu I. to Sitka, Alaska

Spongomorpha mertensii (Ruprecht) Setchell & Gardner

Scagel, 1957
Unalaska, Alaska, to San Francisco, Calif.

Spongomorpha saxatilis (Ruprecht) Collins var. *saxatilis*

Doty, 1947
Alaska to San Francisco, Calif.

Spongomorpha saxatilis var. *chamissonis* (Ruprecht) Collins

Scagel, 1957
Unalaska, Alaska, to Wash.

Spongomorpha spinescens Kützing

Scagel, 1957
Unalaska, Alaska, to Coos Bay, Oreg.

FAM. ANADYOMENACEAE

Valoniopsis hancockii Dawson

Dawson, 1954
Isla Ángel de la Guarda, Gulf of Calif.

Valoniopsis pachynema (Martens) Børgesen

Dawson, 1954, 1959
Scammon Lagoon, Baja Calif.; Isla Ángel de la Guarda to Isla Espíritu Santo, Gulf of Calif.; Isla Isabel, Nayarit

Microdictyon palmeri Setchell

Dawson, 1954
Isla Guadalupe, Baja Calif.

ORDER SIPHONOCLADALES

FAM. VALONIACEAE

Dictyosphaeria australis Setchell

Dawson, 1954
Cabeza Ballena, Baja Calif.; Isla Clarión, Revillagigedo Arch.

Dictyosphaeria versluysii Weber van Bosse

Dawson, 1954, 1954*c*
Isla Guadalupe, Baja Calif.; Isla Espíritu Santo, Gulf of Calif.; Revillagigedo Arch.

FAM. SIPHONOCLADACEAE

Siphonocladus pusilloides Setchell & Gardner

Dawson, 1954
Isla Guadalupe, Baja Calif.

Ernodesmis verticillata (Kützing) Børgesen

Dawson, 1954, 1959
Cabeza Ballena, Baja Calif. del Sur; Isla Carmén; La Paz, Gulf of Calif.

Cladophoropsis fasciculata (Kjellman) Børgesen

Dawson, 1958, 1959*c*
Lechuza Point; Dana Point, Calif.

Cladophoropsis gracillima Dawson

Dawson, 1954, 1957*b*, 1960*a*
Punta Palmilla, Baja Calif.; Costa Rica

Cladophoropsis membranacea (C. Agardh) Børgesen

Dawson, 1960*a* ("*Cladophora*" by error)
Punta Cono, Baja Calif.

Cladophoropsis (?) *robusta* Setchell & Gardner

Dawson, 1954 (as *Willeella mexicana* in part), 1957*b* (as *Willeella mexicana*), 1959
Southern Gulf of Calif.

FAM. BOODLEACEAE

Struvea anastomosans (Harvey) Piccone
Dawson, 1954, 1957*b*
Acapulco, Guerrero; Costa Rica

Boodlea composita (Harvey & Hooker, f.) Brand
Taylor, 1945; Dawson, 1954
Isla María Magdalena, Nayarit; Guayas, Ecuador

Boodlea siamensis Reinbold
Dawson, 1957*b*
Golfo Dulce, Costa Rica

ORDER SIPHONALES

FAM. DERBESIACEAE

Halicystis ovalis (Lyngbye) Areschoug
Scagel, 1957; Dawson, Neushul, Wildman, 1960, 1960*a* (Note: this is generally recognized as the gametophyte phase of *Derbesia marina*)
Silver Bay, Alaska, to Punta Eugenio, Baja Calif.

Derbesia attenuata Dawson
Dawson, 1959*b*, 1960*a*
Clipperton I.; Isla Brincanco, Panamá

Derbesia hollenbergii Taylor
Taylor, 1945; Dawson, 1959
Isla Carmén, Gulf of Calif.; Galapagos Arch.

Derbesia lamourouxii (J. Agardh) Solier
Dawson, 1954
Near Tijuana; Cabo Colnett, Baja Calif.

Derbesia longifructa Taylor
Taylor, 1945
Guayas, Ecuador

Derbesia marina (Lyngbye) Kjellman
Scagel, 1957 (Note: this is generally recognized as the sporophyte phase of *Halicystis ovalis*)
Sitka, Alaska, to La Jolla, Calif.

Derbesia pacifica Jao
Scagel, 1957
Turn I., Wash.

Derbesia prolifica Taylor
Taylor, 1945
Galapagos Arch.

Derbesia tenuissima (De Notaris) Crouan & Crouan ?
Dawson, 1954
Campo Malarrimo, Bahia Vizcaino, Baja Calif.

Derbesia vaucheriaeformis (Harvey) J. Agardh
Scagel, 1957
Yakutat Bay, Alaska, to northern Wash.

FAM. CAULERPACEAE

Caulerpa cupressoides var. *lycopodium* near f. *elegans* Weber van Bosse
Taylor, 1945
Isla Gorgona, Colombia

Caulerpa pinnata f. *pectinata* (Kützing) Weber van Bosse
Dawson, 1954
Isla Ángel de la Guarda, Gulf of Calif.

Caulerpa racemosa var. *clavifera* f. *macrophysa* (Kützing) Weber van Bosse
Dawson, 1954
Isla Guadalupe, Baja Calif.

Caulerpa racemosa var. *laetevirens* (Montagne) Weber van Bosse f. *laetevirens*
Dawson, 1954
Isla Guadalupe, Baja Calif.; Isla Clarión, Revillagigedo Arch.

Caulerpa racemosa var. *laetevirens* f. *cylindraceae* (Sonder) Weber van Bosse
Dawson, 1954
Isla Guadalupe, Baja Calif.; Clipperton I.

Caulerpa racemosa var. *occidentalis* (C. Agardh) Børgesen
Taylor, 1945; Dawson, 1954
Isla Clarión, Revillagigedo Arch.; Galapagos Arch.

Caulerpa racemosa var. *turbinata* (J. Agardh) Eubank

Dawson, 1954, 1959
Southern Gulf of Calif. to Mazatlán, Sinaloa

Caulerpa racemosa var. *uvifera* (Turner) Weber van Bosse

Dawson, 1954; Taylor, 1945
Isla Espíritu Santo, Gulf of Calif.; Galapagos Arch.

Caulerpa sertularioides (Gmelin) Howe

Dawson, 1954, 1959
Puerto Escondido to La Paz, Gulf of Calif.; Tangola-Tangola, Oaxaca

Caulerpa vanbosseae Setchell & Gardner

Dawson, 1954, 1959; Dawson, Neushul, Wildman, 1960*a*
Vicinity of Bahía Magdalena, Baja Calif.; Isla Ángel de la Guarda to Isla Espíritu Santo, Gulf of Calif.

FAM. BRYOPSIDACEAE

Pseudobryopsis hainanensis Tseng

Dawson, 1954*c*
Isla San Benedicto, Revillagigedo Arch.

Bryopsis corticulans Setchell

Dawson, 1954; Scagel, 1957; Dawson, 1959*c*
Southern British Columbia to La Jolla, Calif.; Islas San Benitos, Baja Calif.

Bryopsis galapagensis Taylor

Taylor, 1945; Dawson, 1954
Revillagigedo Arch.; Galapagos Arch.; Isla Gorgona, Colombia

Bryopsis hypnoides Lamouroux

Dawson, 1954; Scagel, 1957; Dawson, 1959*c*
Southern British Columbia to San Pedro, Calif.; La Paz, Gulf of Calif.; Panama City, Panamá

Bryopsis muscosa Lamouroux

Dawson, 1954, 1959
Pacific Baja Calif.; southern Gulf of Calif.; Salina Cruz, Oaxaca

Bryopsis pennata Lamouroux

Dawson, 1954 (as *B. pennatula* and as *B. plumosa* var. *pennata*), 1957*b*, 1959
Isla Tiburón, Gulf of Calif., to Golfo de Nicoya, Costa Rica

Bryopsis pennatula J. Agardh

Taylor, 1945; Dawson, 1954. (Note: probably equal to *B. pennata* according to Dawson, 1959)
Guerrero; Oaxaca; Galapagos Arch.

Bryopsis plumosa (Hudson) C. Agardh

Scagel, 1957
Southern British Columbia to northern Wash.

FAM. CODIACEAE

Boodleopsis verticillata Dawson

Dawson, 1960*a*
Isla del Rey, Panamá

Chlorodesmis hildebrandtii A. Gepp & E. Gepp

Dawson, 1957*b*, 1959
Southern Gulf of Calif.; Costa Rica

Chlorodesmis mexicana Taylor

Taylor, 1945; Dawson, 1954
Isla Guadalupe, Baja Calif., to Tangola-Tangola, Oaxaca; Guayas, Ecuador; Galapagos Arch.

Geppella decussata Dawson

Dawson, 1959
Isla San Francisco, Gulf of Calif.

Codium amplivesiculatum Setchell & Gardner

Dawson, 1954, 1959
Isla Pond; Puerto Escondido, Gulf of Calif.

Codium anastomosans Setchell & Gardner

Dawson, 1954 (Note: probably equal to *C. simulans*)
Isla Ángel de la Guarda to Isla Tiburón, Gulf of Calif.

Codium cervicorne Setchell & Gardner

Taylor, 1945
Galapagos Arch.

Codium cuneatum Setchell & Gardner

Dawson, 1954; Dawson, Neushul, Wildman, 1960, 1960*a*
San Pedro, Calif., to southern Baja Calif; Gulf of Calif.

Codium decorticatum (Woodward) Howe

Dawson, 1954
Isla Clarión, Revillagigedo Arch.

Codium dichotomum (Hudson) S. F. Gray

Taylor, 1945; Dawson, 1954
Isla Guadalupe; Isla Cedros to Isla Magdalena, Baja Calif.; Mazatlán, Sinaloa; Galapagos Arch.

Codium fernandezianum Setchell

Taylor, 1945; Dawson, 1954
Bahía Santa María, Baja Calif.; Guayas, Ecuador

Codium foveolatum Howe, prox.

Taylor, 1945
Galapagos Arch.

Codium fragile (Suringar) Hariot

Scagel, 1957; Dawson, 1954, 1959*c*
Sitka, Alaska, to Bahía Asunción, Baja Calif.

Codium geppii O. C. Schmidt, complex

Dawson, 1959*b*
Clipperton I.

Codium hubbsii Dawson

Dawson, 1954; Dawson, Neushul, Wildman, 1960
Santa Catalina I., Calif., to Bahía Asunción, Baja Calif.; Isla Guadalupe, Baja Calif.

Codium isabelae Taylor

Dawson, 1954
Isla Clarión, Revillagigedo Arch.; La Paz, Baja Calif.

Codium johnstonei Silva

Dawson, 1954
Santa Cruz I., Calif. to Islas Coronados, Baja Calif.

Codium longiramosum Setchell & Gardner

Dawson, 1954
Isla Pond, Gulf of Calif.; Isla Clarión, Revillagigedo Arch.; Bahía Petatlán, Guerrero

Codium macdougalii Dawson

Dawson, 1954
Puerto Libertad, Sonora

Codium magnum Dawson

Dawson, 1954
Bahía San Quintín, Baja Calif.

Codium palmeri Dawson

Dawson, 1954
Isla Guadalupe, Baja Calif.

Codium santamariae Taylor

Taylor, 1945
Galapagos Arch,; Guayas, Ecuador

Codium setchellii Gardner

Dawson, 1954; Scagel, 1957; Dawson, 1957, 1959*c*; Dawson, Neushul, Wildman, 1960, 1960*a*
Sitka, Alaska, to Punta Abreojos, Baja Calif.; Rocas Alijos

Codium simulans Setchell & Gardner

Dawson, 1954, 1959
Ensenada ?; Isla Guadalupe ?; Punta Santa Rosalía, Baja Calif.; Gulf of Calif.; Isla Clarión, Revillagigedo Arch.

Codium ritteri Setchell & Gardner

Scagel, 1957
Kodiak I., Alaska, to Vancouver I., British Columbia

Halimeda discoidea Decaisne

Dawson, 1954, 1957*b*, 1959
Isla Magdalena, Baja Calif.; Isla Ángel de la Guarda, Gulf of Calif., to Golfo Dulce, Costa Rica

Halimeda opuntia (Linnaeus) Lamouroux

Dawson, 1954
Isla Guadalupe, Baja Calif.; Isla Clarión, Revillagigedo Arch.

Halimeda tuna (Solander) Lamouroux

Dawson, 1954
Isla Clarión, Revillagigedo Arch.

ORDER **DASYCLADALES**

FAM. DASYCLADACEAE

Acetabularia moebii Solms-Laubach

Dawson, 1960*a*
Revillagigedo Arch.; Bahía Carrizal, Colima

Neomeris annulata Dickie

Dawson, 1959
Isla Partida, southern Gulf of Calif.

Neomeris vanbosseae Howe

Dawson, 1954
Isla Socorro, Revillagigedo Arch.

PHYLUM **CHRYSOPHYCOPHYTA**

ORDER **VAUCHERIALES**

FAM. PHYLLOSIPHONACEAE

Ostreobium quekettii Bornet & Flahault

Scagel, 1957
Puget Sound, Wash.

Ostreobium reineckei Bornet

Dawson, 1954
Isla Guadalupe, Baja Calif.; Isla Clarión, Revillagigedo Arch.

FAM. VAUCHERIACEAE

Vaucheria litoria Bang & C. Agardh

Scagel, 1957
Northern Wash.

Vaucheria longicaulis Hoppaugh

Hoppaugh, 1930; Taylor, 1952
Elkhorn Slough, Monterey Co., Calif.

Vaucheria thuretii Woronin

Doty, 1947
Charleston, Oreg.

PHYLUM **PHAEOPHYCOPHYTA**

ORDER **ECTOCARPALES**

FAM. ECTOCARPACEAE

Pylaiella gardneri Collins

Smith, 1944
San Francisco to Carmel, Calif.

Pylaiella littoralis (Linnaeus) Kjellman

Scagel, 1957
Bering Sea to San Pedro, Calif.

Pylaiella tenella Setchell & Gardner

Scagel, 1957
Neah Bay, Wash.; Monterey, Calif.

Pylaiella unilateralis Setchell & Gardner

Setchell & Gardner, 1925; Doty, 1947
Coos Bay, Oreg.

Pylaiella washingtoniensis Jao

Scagel, 1957
Northern Wash.

(Note: Hamel (1939) and others treat some species of *Ectocarpus* under the separate genera *Giffordia* and *Feldmannia*)

Ectocarpus acuminatus Saunders

Smith, 1944
Pacific Grove to San Pedro, Calif.

Ectocarpus acutus Setchell & Gardner var. *acutus*

Scagel, 1957
Puget Sound to Carmel, Calif.

Ectocarpus acutus var. *haplogloiae* Doty

Doty, 1947; Scagel, 1957
Neah Bay, Wash.; Oreg.; Moss Beach, Calif.

Ectocarpus affinis Setchell & Gardner

Setchell & Gardner, 1925
Sitka, Alaska

Ectocarpus breviarticulatus J. Agardh

Dawson, 1954, 1954*c*
Isla Guadalupe, Baja Calif.; Isla San Benedicto, Revillagigedo Arch.; San Agustín, Oaxaca

Ectocarpus bryantii Setchell & Gardner

Dawson, 1954
La Paz, Gulf of Calif.

Ectocarpus chantransioides Setchell & Gardner

Setchell & Gardner, 1925; Hollenberg, 1948
Santa Monica; Corona del Mar, Calif.

Ectocarpus chitonicola Saunders

Smith, 1944
Monterey Peninsula, Calif.

Ectocarpus commensalis Setchell & Gardner

Smith, 1944; Dawson, 1954
Monterey Peninsula, Calif.; Campo Malarrimo, Bahía Vizcaino, Baja Calif.

Ectocarpus confervoides (Roth) LeJolis f. *confervoides*

Coe, 1932; Scagel, 1957
Yakutat Bay, Alaska, to La Jolla, Calif.

Ectocarpus confervoides f. *parvus* (Saunders) Setchell & Gardner

Setchell & Gardner, 1925
San Francisco to San Diego, Calif.

Ectocarpus confervoides f. *typicus* Kuckuck

Setchell & Gardner, 1925; Doty, 1947
Juneau, Alaska, to San Francisco, Calif.

Ectocarpus corticulatus Saunders

Scagel, 1957
Popof I., Alaska, to San Pedro, Calif.

Ectocarpus cylindricus Saunders f. *cylindricus*

Coe, 1932; Hollenberg, 1948; Scagel, 1957
Northern Wash. to La Jolla, Calif.

Ectocarpus cylindricus f. *codiophilus* Setchell & Gardner

Smith, 1944; Dawson, 1945*b*, 1960*a*
Monterey Peninsula; La Jolla, Calif.; Punta Thurloe, Baja Calif.

Ectocarpus dimorphus Silva

Dawson, 1954 (as *E. variabilis*); Silva, 1957; Scagel, 1957
Hope I., British Columbia, to Bahía Asunción, Baja Calif.; Gulf of Calif.

Ectocarpus duchassaignianus Grunow

Dawson, 1954
Isla Guadalupe, Baja Calif.; Isla María Magdalena, Nayarit; Isla Socorro, Revillagigedo Arch.

Ectocarpus ellipticus Saunders

Smith, 1944
Monterey Peninsula, Calif.

Ectocarpus ensenadanus Gardner

Dawson, 1954
Ensenada, Baja Calif.

Ectocarpus eramosus Setchell & Gardner

Setchell & Gardner, 1925
Tomales Bay, Calif.

Ectocarpus flagelliferus Setchell & Gardner

Setchell & Gardner, 1925
Sitka, Alaska

Ectocarpus flocculiformis Setchell & Gardner

Setchell & Gardner, 1925; Dawson, 1954
La Jolla, Calif.; Isla Cedros; Campo Malarrimo, Baja Calif.

Ectocarpus fructuosus Setchell & Gardner

Setchell & Gardner, 1925
Moss Beach, Calif.

Ectocarpus globifer Kützing

Setchell & Gardner, 1925
San Pedro to La Jolla, Calif.

Ectocarpus gonodioides Setchell & Gardner

Smith, 1944; Dawson, 1954
Carmel, Calif.; Isla Smith, Gulf of Calif.

Ectocarpus granulosoides Setchell & Gardner var. *granulosoides*

Smith, 1944; Dawson, 1945*b*
Monterey to La Jolla, Calif.

Ectocarpus granulosoides var. *pygmaeus* Setchell & Gardner

Dawson, 1954
Isla San Martín, Baja Calif.

Ectocarpus granulosus (J. E. Smith) C. Agardh
Coe, 1932; Dawson, 1954; Scagel, 1957; Dawson, 1959*c*, 1960*a*
Southern British Columbia to Punta Thurloe, Baja Calif.

Ectocarpus hancockii Dawson
Dawson, 1954
Isla Turner, Gulf of Calif.

Ectocarpus hemisphericus Saunders f. *hemisphericus*
Setchell & Gardner, 1925
San Pedro to San Diego, Calif.

Ectocarpus hemisphericus f. *minor* Saunders
Setchell & Gardner, 1925; Dawson, 1945*b*
Southern Calif.

Ectocarpus indicus Sonder
Dawson, 1959*b*
Clipperton I.

Ectocarpus irregularis Kützing
Dawson, 1954*c*, 1959*b*
Isla San Benedicto, Revillagigedo Arch.; Clipperton I.?

Ectocarpus isopodicola Dawson
Dawson, 1946
Newport Bay, Calif.

Ectocarpus luteolus Sauvageau
Setchell & Gardner, 1925
San Francisco, Calif.

Ectocarpus mesogloiae Setchell & Gardner
Smith, 1944
Carmel, Calif.

Ectocarpus mitchellae Harvey
Setchell & Gardner, 1925; Dawson, 1954, 1959, 1959*c*
Southern Calif. to San Jose del Cabo, Baja Calif.; Punta Peñasco, Sonora; southern Gulf of Calif. ?

Ectocarpus mucronatus Saunders
Scagel, 1957; Dawson, 1954, 1959*c*
Vancouver I., British Columbia, to San Pedro, Calif.; Punta Peñasco, Sonora

Ectocarpus oviger Harvey
Scagel, 1957
Southern British Columbia to Carmel, Calif.

Ectocarpus saundersii Setchell & Gardner
Smith, 1944
Monterey Peninsula, Calif.

Ectocarpus parksii Setchell & Gardner
Setchell & Gardner, 1925
San Francisco Bay, Calif.

Ectocarpus pygmaeus Areschoug
Dawson, 1954 (as *E. confervoides* f. *pygmaeus*); Scagel, 1957
Shumagin I., Alaska, to Carmel, Calif.; Punta Descanso, Baja Calif.

Ectocarpus siliculosus (Dillwyn) Lyngbye f. *siliculosus*
Setchell & Gardner, 1925; Sanborn & Doty, 1946; Doty, 1947
Coos Bay, Oreg., to San Francisco Bay, Calif.

Ectocarpus siliculosis f. *subulatus* (Kützing) Setchell & Gardner
Setchell & Gardner, 1925
San Francisco Bay, Calif.

Ectocarpus simulans Setchell & Gardner
Smith, 1944
Monterey, Calif.

Ectocarpus socialis Setchell & Gardner
Setchell & Gardner, 1925; Dawson, 1945*b*
Southern Calif.

Ectocarpus sonorensis Dawson
Dawson, 1954
Guaymas, Gulf of Calif.

Ectocarpus taoniae Setchell & Gardner
Setchell & Gardner, 1925
San Pedro, Calif.

Ectocarpus terminalis Kützing
Scagel, 1957
Unalaska, Alaska, to Laguna Beach, Calif.

Ectocarpus tomentosus (Hudson) Lyngbye
Scagel, 1957; Taylor, 1945
Kodiak I., Alaska, to Laguna Beach, Calif.; Galapagos Arch.

Zosterocarpus abyssicolus Taylor
Taylor, 1945
Galapagos Arch.

Streblonema aecidioides f. *pacificum* Setchell & Gardner
Scagel, 1957
Southern British Columbia to northern Wash.

Streblonema anomalus Setchell & Gardner
Smith, 1944
Monterey; San Pedro, Calif.

Streblonema codicola Setchell & Gardner
Dawson, 1954
Isla Guadalupe, Baja Calif.

Streblonema corymbiferum Setchell & Gardner
Smith, 1944
Monterey; San Pedro, Calif.

Streblonema desmarestiae Gardner
Gardner, 1940; Scagel, 1957
San Juan I., Wash.

Streblonema evagatum Setchell & Gardner
Smith, 1944
Monterey, Calif.

Streblonema investiens (Collins) Setchell & Gardner
Setchell & Gardner, 1925; Dawson, 1945*b*
San Pedro to La Jolla, Calif.

Streblonema irregulare Saunders
Setchell & Gardner, 1925
Sitka, Alaska

Streblonema johnstonae Setchell & Gardner
Setchell & Gardner, 1925
San Pedro, Calif.

Streblonema minutissimum Saunders
Setchell & Gardner, 1925
Sitka, Alaska

Streblonema myrionematoides Setchell & Gardner
Setchell & Gardner, 1925
Moss Beach, Calif.

Streblonema pacificum Saunders
Setchell & Gardner, 1925
Yakutat Bay, Alaska, to San Francisco Bay, Calif.

Streblonema penetrale Setchell & Gardner
Smith, 1944
Pacific Grove, Calif.

Streblonema porphyrae Setchell & Gardner
Smith, 1944
Monterey Peninsula, Calif.

Streblonema rugosum Setchell & Gardner
Scagel, 1957
Northern Wash.

Streblonema scabiosum Setchell & Gardner
Setchell & Gardner, 1925
San Francisco, Calif.

Streblonema transfixum Setchell & Gardner
Setchell & Gardner, 1925
San Pedro, Calif.

Streblonema vorax Setchell & Gardner
Setchell & Gardner, 1925
Sitka, Alaska

FAM. RALFSIACEAE

Ralfsia californica Setchell & Gardner
Dawson, 1954
Central Calif.; Isla Tiburón to Isla Espíritu Santo, Gulf of Calif.; Bahía Tenacatita, Jalisco

Ralfsia clavata (Carmichael) Crouan
Setchell & Gardner, 1925
Unalaska Bay, Alaska

Ralfsia fungiformis (Gunnerus) Setchell & Gardner
Scagel, 1957
Bering Sea to Coos Bay, Oreg.

Ralfsia hancockii Dawson

Dawson, 1954, 1954*c*
San Jose del Cabo, Baja Calif.; Isla San Benedicto, Revillagigedo Arch.

Ralfsia hesperia Setchell & Gardner

Smith, 1944
Carmel; Corona del Mar, Calif.

Ralfsia occidentalis Hollenberg

Dawson, 1954
Isla Socorro, Revillagigedo Arch.

Ralfsia pacifica Hollenberg, in Dawson

Dawson, 1954; Scagel, 1957
Unalaska, Alaska, to Baja Calif.; northern Gulf of Calif.

Ralfsia pangoensis var. *galapagensis* Setchell & Gardner

Setchell & Gardner, 1937
Galapagos Arch.

Hapterophycus canaliculatus Setchell & Gardner

Dawson, 1954, 1959*c*
Redondo, Calif., to Islas San Benito, Baja Calif.

Lithoderma fatiscens Areschoug

Setchell & Gardner, 1925
Bering Sea; Unalaska, Alaska

Hapalospongidion gelatinosum Saunders

Smith, 1944; Dawson, 1954
Carmel, Calif., to Punta Banda, Baja Calif.; Bahía Petatlán, Guerrero

ORDER SPHACELARIALES

FAM. SPHACELARIACEAE

Sphacelaria brevicorne Setchell & Gardner

Dawson, 1954
Vicinity of La Paz, Gulf of Calif.

Sphacelaria californica Sauvageau

Setchell & Gardner, 1925
San Pedro to San Diego, Calif.

Sphacelaria didichotoma Saunders

Smith, 1944
Monterey to southern Calif.

Sphacelaria furcigera Kützing

Dawson, 1954, 1957*b*, 1959, 1959*b*
La Jolla, Calif., to Isla Magdalena, Baja Calif.; Gulf of Calif.; Golfo de Nicoya, Costa Rica; Clipperton I.; Galapagos Arch.

Sphacelaria hancockii Dawson

Dawson, 1954, 1959
Bahía Viscaino, Baja Calif.; Gulf of Calif.

Sphacelaria masonii Setchell & Gardner

Dawson, 1954
Isla Clarión, Revillagigedo Arch.

Sphacelaria novae-hollandiae Sonder

Dawson, 1954, 1957*b*
Isla Guadalupe, Baja Calif.; Golfo Dulce, Costa Rica

Sphacelaria racemosa Greville

Scagel, 1957
Bering Sea to Oreg.

Sphacelaria subfusca Setchell & Gardner

Scagel, 1957
Sitka, Alaska, to Redondo, Calif.

Sphacelaria tribuloides Meneghini

Dawson, 1959
Isla San Diego, Gulf of Calif.

ORDER CUTLERIALES

FAM. CUTLERIACEAE

Cutleria hancockii Dawson

Dawson, 1954
Northern Gulf of Calif.

ORDER TILOPTERIDALES

FAM. TILOPTERIDACEAE

Masonophycus paradoxa Setchell & Gardner

Dawson, 1954
Isla Clarión, Revillagigedo Arch.

ORDER **DICTYOTALES**

FAM. DICTYOTACEAE

Pachydictyon coriaceum (Holmes) Okamura

Dawson, 1954, 1959, 1959*c*; Dawson, Neushul, Wildman, 1960

Coos Bay, Oreg., to Punta Entrada, Isla Magdalena, Baja Calif.; northern Gulf of Calif. south to Isla Ildefonso

Dictyota binghamiae J. Agardh

Dawson, 1954; Dawson, Neushul, Wildman, 1960, 1960*a*

Coos Bay, Oreg., to central Baja Calif.

Dictyota concrescens Taylor

Dawson, 1954

Cabo San Lazaro, Isla Magdalena, Baja Calif.

Dictyota crenulata J. Agardh

Dawson, 1954, 1954*c*, 1959

Isla San Benedicto, Revillagigedo Arch.; Isla San Diego, Gulf of Calif., to Puerto Culebra, Costa Rica

Dictyota dichotoma (Hudson) Lamouroux

Dawson, 1954, 1957, 1959

Gulf of Calif.; tropical Pacific Mexico and Central America ?; Galapagos Arch.

Dictyota divaricata Lamouroux

Dawson, 1954, 1957, 1957*b*, 1959

Isla Guadalupe, Baja Calif.; Revillagigedo Arch.; La Paz, Gulf of Calif., to Isla La Plata, Ecuador

Dictyota flabellata (Collins) Setchell & Gardner

Smith, 1944; Taylor, 1945; Doty, 1947; Dawson, 1954, 1959, 1959*c*; Dawson, Neushul & Wildman, 1960

Southern Calif. to Punta Santa Rosalía, Baja Calif.; northern Gulf of Calif. south to Isla Tortuga

Dictyota friabilis Setchell

Dawson, 1957*b*; Dawson, Neushul & Wildman, 1960*a*

Islas San Benito, Baja Calif.; Golfo de Nicoya, Costa Rica ?

Dictyota major Taylor

Taylor, 1945

Galapagos Arch.

Dictyota masonii Setchell & Gardner

Dawson, 1954, 1960*a*

Isla Margarita, Baja Calif. ?; Isla Clarión, Revillagigedo Arch., Isla del Caño, Costa Rica ?

Dilophus okamurai Dawson

Dawson, 1954

Vicinity of San Lucas, Baja Calif.

Dilophus pinnatus Dawson

Dawson, 1954

Miramar, Nayarit

Dictyopteris cokeri (Howe) Taylor

Taylor, 1945

Galapagos Arch.

Dictyopteris delicatula Lamouroux

Dawson, 1954

Revillagigedo Arch.; Clipperton I.

Dictyopteris diaphana Taylor

Taylor, 1945

Galapagos Arch.

Dictyopteris johnstonei Gardner

Silva, 1957 (indicating probable identity with *D. zonarioides*)

Santa Cruz I., Calif., to Islas San Benitos, Baja Calif.

Dictyopteris membranacea (Stackhouse) Batters

Dawson, 1954

Isla Guadalupe; Scammons Lagoon, Baja Calif.

Dictyopteris repens (Okamura) Børgesen

Dawson, 1957, 1957*b*, 1959, 1959*b*

Isla Carmén, Gulf of Calif.; Golfo de Nicoya, Costa Rica; Clipperton I.

Dictyopteris zonarioides Farlow

Dawson, 1954, 1959, 1959*c*; Dawson, Neushul & Wildman, 1960

Southern Calif. to San Jose del Cabo, Baja Calif.; northern Gulf of Calif. south to Isla Ildefonso

Taonia lennebackerae Farlow

Dawson, 1954, 1959*c*; Dawson, Neushul, Wildman, 1960, 1960*a*
Lechuza Point, Calif., to Bahía Asunción, Baja Calif.

Syringoderma abyssicola (Setchell & Gardner) Levring

Scagel, 1957
Northern Wash.

Spatoglossum ecuadoreanum Taylor

Taylor, 1945
Galapagos Arch.

Spatoglossum howellii Setchell & Gardner

Dawson, 1954; Dawson, Neushul, Wildman, 1960*a*
Central Baja Calif.; Galapagos Arch.

Spatoglossum lanceolatum Dawson

Dawson, 1954
Ensenada de San Francisco, Sonora

Spatoglossum sp. aff. *S. schroederi* (Mertens) J. Agardh

Dawson, 1959
Isla San Pedro Nolasco, Gulf of Calif.

Spatoglossum schmittii Taylor

Taylor, 1945
Galapagos Arch.

Spatoglossum subflabellatum Dawson

Dawson, 1954
Ensenada de San Francisco, Sonora

Glossophora galapagensis Taylor

Taylor, 1945
Galapagos Arch.

Zonaria lobata C. Agardh

Taylor, 1945
Galapagos Arch.

Zonaria farlowii Setchell & Gardner

Dawson, 1954, 1959*c*; Dawson, Neushul, Wildman, 1960
Santa Barbara Co., Calif., to Isla Magdalena, Baja Calif.

Pocockiella variegata (Lamouroux) Papenfuss

Taylor, 1945; Dawson, 1954, 1954*c*, 1957, 1957*b*, 1959, 1959*b*
Rocas Alijos, Baja Calif.; Revillagigedo Arch.; southern Gulf of Calif.; Costa Rica; Guayas, Ecuador; Galapagos, Arch.; Clipperton I.

Padina caulescens Thivy

Dawson, 1954, 1957*b*, 1959
Isla Monserrate, Gulf of Calif.; Isla María Magdalena, Nayarit; Golfo de Nicoya, Costa Rica

Padina concrescens Thivy

Taylor, 1945
Galapagos Arch.

Padina crispata Thivy

Dawson, 1954, 1957*b*, 1959
Southern Gulf of Calif. to Bahía Honda, Panamá

Padina durvillaei Bory

Taylor, 1945; Dawson, 1954, 1957, 1957*b*, 1959; Dawson, Neushul, Wildman, 1960
Punta María, Baja Calif., to Guayas, Ecuador; Galapagos Arch.

Padina mexicana Dawson

Dawson, 1954, 1959
Isla Turner to La Paz, Gulf of Calif.

Padina tetrastromatica Hauck

Dawson, 1954
Isla María Madre, Nayarit ?

ORDER CHORDARIALES

FAM. MYRIONEMATACEAE

Myrionema attenuatum Setchell & Gardner

Smith, 1944
Monterey Peninsula, Calif.

Myrionema balticum f. *californicum* Setchell & Gardner

Smith, 1944
Monterey Peninsula, Calif.

Myrionema balticum f. *pedicellatum* Setchell & Gardner

Setchell & Gardner, 1925
Point Carmel, Calif.

Myrionema compsonematoides Setchell & Gardner

Scagel, 1957
Friday Harbor, Wash.

Myrionema corunnae f. *angulatum* Setchell & Gardner

Setchell & Gardner, 1925
San Francisco, Calif.

Myrionema corunnae f. *sterile* Setchell & Gardner

Smith, 1944
Carmel, Calif.

Myrionema corunnae f. *uniforme* Setchell & Gardner

Setchell & Gardner, 1925
San Mateo Co., Calif.

Myrionema foecundum f. *ramulosum* Setchell & Gardner

Scagel, 1957
Friday Harbor, Wash.

Myrionema foecundum f. *simplicissimum* Setchell & Gardner

Scagel, 1957
Kodiak I., Alaska, to central Calif.

Myrionema foecundum f. *subulatum* Setchell & Gardner

Setchell & Gardner, 1925
San Francisco, Calif.

Myrionema globosum f. *affine* Setchell & Gardner

Scagel, 1957
Sitka, Alaska, to Point Carmel, Calif.

Myrionema minutissimum Setchell & Gardner

Setchell & Gardner, 1925
San Francisco, Calif.

Myrionema obscurum Setchell & Gardner

Setchell & Gardner, 1925
Moss Beach, Calif.

Myrionema phyllophyllum Setchell & Gardner

Setchell & Gardner, 1925
Sitka, Alaska

Myrionema primarium Setchell & Gardner

Scagel, 1957
Alaska to Carmel, Calif.

Myrionema setiferum Setchell & Gardner

Setchell & Gardner, 1925
Sitka, Alaska

Myrionema strangulans Greville

Scagel, 1957
Sitka, Alaska, to Carmel, Calif.

Compsonema coniferum Setchell & Gardner

Smith, 1944
Monterey Peninsula, Calif.

Compsonema dubium Setchell & Gardner

Smith, 1944
Monterey Peninsula, Calif.

Compsonema fasciculatum Setchell & Gardner

Smith, 1944
Pacific Grove, Calif.

Compsonema fructuosum Setchell & Gardner

Setchell & Gardner, 1925
Tomales Bay, Calif.

Compsonema immixtum Setchell & Gardner

Dawson, 1954
Isla Partida, Gulf of Calif.

Compsonema intricatum Setchell & Gardner

Smith, 1944
Carmel, Calif.

Compsonema myrionematoides Setchell & Gardner

Smith, 1944
Pacific Grove, Calif.

Compsonema nummuloides Setchell & Gardner
Setchell & Gardner, 1925
Moss Beach, Calif.

Compsonema pusillum Setchell & Gardner
Smith, 1944
Carmel, Calif.

Compsonema ramulosum Setchell & Gardner
Smith, 1944
Carmel, Calif.

Compsonema secundum Setchell & Gardner
Smith, 1944
Moclips, Wash., to Carmel, Calif.

Compsonema serpens Setchell & Gardner
Smith, 1944
Monterey Peninsula, Calif.

Compsonema sessile Setchell & Gardner
Scagel, 1957
Neah Bay, Wash.

Compsonema speciosum f. *piliferum* Setchell & Gardner
Setchell & Gardner, 1925
Moclips, Wash.

Compsonema sporangiiferum Setchell & Gardner
Scagel, 1957
Neah Bay, Wash.

Compsonema streblonematoides Setchell & Gardner
Setchell & Gardner, 1925
Tomales Bay, Calif.

Compsonema tenue Setchell & Gardner
Setchell & Gardner, 1925
Sitka, Alaska

Hecatonema clavatum Setchell & Gardner
Setchell & Gardner, 1925
Tomales Bay, Calif.

Hecatonema lawsonii Setchell & Gardner
Setchell & Gardner, 1925
Uyak Bay, Alaska

Hecatonema variabile Setchell & Gardner
Smith, 1944
Monterey Peninsula, Calif.

FAM. ELACHISTACEAE

Halothrix lumbricalis (Kützing) Reinke
Dawson, 1954
Isla Guadalupe, Baja Calif.

Elachistea fucicola (Velley) Areschoug
Scagel, 1957
Sitka, Alaska, to Coos Bay, Oreg.

Elachistea lubrica Ruprecht
Setchell & Gardner, 1925
Prince William Sound to Wrangell, Alaska

Gonodia johnstonii Setchell & Gardner
Dawson, 1954
Isla San Marcos, Gulf of Calif.

Gonodia marchantae Setchell & Gardner
Dawson, 1954
La Paz, Gulf of Calif.

FAM. CORYNOPHLOEACEAE

Petrospongium rugosum (Okamura) Setchell & Gardner
Smith, 1944; Dawson, 1954, 1959*c*
San Mateo Co., Calif., to Bahía Asunción, Baja Calif.

Leathesia difformis (Linnaeus) Areschoug
Coe, 1932; Dawson, 1954; Scagel, 1957; Dawson, 1959*c*
Bering Sea to Bahía Asunción, Baja Calif.

Leathesia nana Setchell & Gardner
Smith, 1944; Doty, 1947; Dawson, 1958, 1959*c*
Oreg.; Monterey Peninsula; Carpinteria, Calif.

FAM. CHORDARIACEAE

Eudesme virescens (Carmichael) J. Agardh
Scagel, 1957
Shumagin I. to Sitka, Alaska; La Jolla, Calif.

Haplogloia andersonii (Farlow) Levring
Scagel, 1957; Dawson, 1954
Sitka, Alaska, to Cabo Colnett, Baja Calif.

Haplogloia kuckuckii Kylin
Scagel, 1957
Sitka, Alaska, to Friday Harbor, Wash.

Chordaria dissessa Setchell & Gardner
Scagel, 1957
Northern Wash.

Chordaria flagelliformis (Müller) C. Agardh
Setchell & Gardner, 1925
Bering Sea to Sitka, Alaska

Chordaria gracilis Setchell & Gardner
Setchell & Gardner, 1925
Unalaska, Alaska

Saundersella simplex (Saunders) Kylin
Scagel, 1957
Cook Inlet, Alaska, to southern British Columbia

Heterochordaria abietina (Ruprecht) Setchell & Gardner
Okamura, 1933; Scagel, 1957
Bering Sea to Point Conception, Calif.

FAM. SPERMATOCHNACEAE

Nemacystus brandegeei (Setchell & Gardner) Kylin
Dawson, 1954, 1959
Scammon Lagoon, Baja Calif.; Gulf of Calif.

ORDER **SPOROCHNALES**

FAM. SPOROCHNACEAE

Carpomitra costata (Stackhouse) Batters
Dawson, Neushul, Wildman, 1960*a*
Vancouver I., British Columbia; Bahía Viscaino, Baja Calif.

Carpomitra luxurians Taylor
Taylor, 1945
Galapagos Arch.

Sporochnus bolleanus Montagne
Taylor, 1945; Dawson, Neushul, Wildman, 1960*a*
Isla Guadalupe; central Baja Calif.; Galapagos Arch.

Sporochnus pedunculatus (Hudson) C. Agardh
Dawson, 1954; Dawson, Neushul, Wildman, 1960*a*
Isla Guadalupe; Scammon Lagoon, Baja Calif.

Sporochnus rostratus Taylor
Taylor, 1945
Galapagos Arch.

ORDER **DESMARESTIALES**

FAM. DESMARESTIACEAE

Desmarestia farcta Setchell & Gardner
Scagel, 1957
Northern Wash.

Desmarestia filamentosa Dawson
Dawson, 1954
Isla Ángel de la Guarda, Gulf of Calif.

Desmarestia foliacea Pease
Scagel, 1957
Northern Wash.

Desmarestia herbacea (Turner) Lamouroux
Scagel, 1957; Dawson, 1959*c*; Dawson, Neushul, Wildman, 1960
Kodiak Is., Alaska, to Isla Cedros, Baja Calif.

Desmarestia intermedia Postels & Ruprecht
Scagel, 1957
Bering Sea to Oreg.

Desmarestia jordanii Gardner
Gardner, 1940
Ventura, Calif.

Desmarestia latifrons (Ruprecht) Kützing
Doty, 1947
Coos Bay, Oreg., to Point Sur, Calif.

Desmarestia latissima Setchell & Gardner
Scagel, 1957
Northern Wash.

Desmarestia ligulata (Lightfoot) Lamouroux

Scagel, 1957
Southern British Columbia to northern Wash.

Desmarestia linearis Gardner, in Smith

Smith, 1944
Monterey Peninsula, Calif.

Desmarestia media (C. Agardh) Greville var. *media*

Setchell & Gardner, 1925; Okamura, 1933
Atka I., to Unalaska, Alaska

Desmarestia media var. *tenuis* Setchell & Gardner

Scagel, 1957
Juneau, Alaska, to Puget Sound, Wash.

Desmarestia mexicana Dawson

Dawson, 1954
Isla Ángel de la Guarda, Gulf of Calif.

Desmarestia munda Setchell & Gardner

Scagel, 1957; Dawson, Neushul, Wildman, 1960
Northern British Columbia to Punta Pequeña, Baja Calif.; Galapagos Arch.

Desmarestia pacifica Setchell & Gardner

Dawson, 1954
Santa Catalina I., Calif.; Isla Guadalupe, Baja Calif. ?

Desmarestia tabacoides Okamura

Dawson, 1950*a*; Dawson, Neushul, Wildman, 1960
Santa Cruz I. to La Jolla, Calif.

Desmarestia tropica Taylor

Taylor, 1945
Galapagos Arch.

Desmarestia viridis (Müller) Lamouroux

Scagel, 1957
Alaska to Carmel, Calif.

ORDER DICTYOSIPHONALES

FAM. STRIARIACEAE

Stictyosiphon tortilis (Ruprecht) Reinke

Scagel, 1957
Port Clarence, Alaska; Monterey Peninsula, Calif.

FAM. PUNCTARIACEAE

Punctaria chartacea Setchell & Gardner

Setchell & Gardner, 1925
Sitka, Alaska

Punctaria expansa Setchell & Gardner

Scagel, 1957
Southern British Columbia to northern Wash.

Punctaria hesperia Setchell & Gardner

Scagel, 1957
Victoria, British Columbia; Monterey; San Pedro, Calif.

Punctaria latifolia Greville

Setchell & Gardner, 1925
Metlacatla; Baranoff I., Alaska

Punctaria lobata (Saunders) Setchell & Gardner

Setchell & Gardner, 1925
Prince William Sound to Sitka, Alaska

Punctaria occidentalis Setchell & Gardner

Smith, 1944
Monterey, Calif.

Punctaria orbiculata Jao

Scagel, 1957
San Juan I., Wash.

Punctaria plantaginea Greville

Saunders, 1901; Setchell & Gardner, 1925
Yakutat Bay, Alaska ?

Halorhipis winstonii (Anderson) Saunders

Smith, 1944
Monterey Peninsula, Calif.

Soranthera ulvoidea Postels & Ruprecht f. *ulvoidea*

Scagel, 1957; Dawson, 1958, 1959*c*
Bering Sea to Government Point, Calif.

Soranthera ulvoidea f. *difformis* Setchell & Gardner

Scagel, 1957
Bering Sea to Cape Flattery, Wash.

Myelophycus intestinale Saunders

Okamura, 1933; Scagel, 1957
Atka I., Alaska, to Puget Sound, Wash.

Ishige foliaceae Okamura

Dawson, 1954; Setchell & Gardner, 1924 (as *Polyopes sinicola*)
Northern Gulf of Calif.

Phaeostrophion australe Dawson

Dawson, 1958, 1959*c*
Government Point, Calif.

Phaeostrophion irregulare Setchell & Gardner

Setchell & Gardner, 1925; Doty, 1947
Coos Bay, Oreg.; Bolinas, Calif.

FAM. SCYTOSIPHONACEAE

Scytosiphon attenuatus (Foslie) Doty

Doty, 1947
Coos Bay, Oreg. to central Calif.

Scytosiphon bullosus Saunders

Dawson, 1954; Scagel, 1957
Cook Inlet, Alaska, to central Calif.; central Baja Calif.; Gulf of Calif.; Galapagos Arch.

Scytosiphon complanatus (Rosenvinge) Doty

Doty, 1947
Cape Arago, Oreg., to Carmel, Calif.

Scytosiphon lomentaria (Lyngbye) J. Agardh f. *lomentaria*

Coe, 1932; Dawson, 1954; Scagel, 1957; Dawson, 1959*c*
Bering Sea to Islas San Benito, Baja Calif.

Scytosiphon lomentaria f. *cylindricus* subf. *maculatus* Setchell & Gardner

Setchell & Gardner, 1925
San Francisco, Calif.

Scytosiphon complanatus (Rosenvinge) Doty

Doty, 1947
Cape Arago, Oreg., to Carmel, Calif.

Petalonia debilis (C. Agardh) Derbès & Solier f. *debilis*

Coe, 1932 (as *Ilea fascia*); Dawson, 1954 (as *Ilea fascia*); Scagel, 1957; Dawson, 1960*a*; (see also Setchell & Gardner, 1925 for *Ilea fascia* f. *caespitosa* and *Ilea fascia* f. *zosterifolia*)
Unalaska, Alaska, to Isla Magdalena, Baja Calif.

Endarachne binghamiae J. Agardh

Dawson, 1954, 1959*c*
Southern Calif. to Bahía Asunción, Baja Calif.

Colpomenia mollis Taylor

Taylor, 1945
Isla Gorgona, Colombia

Colpomenia ramosa Taylor

Dawson, 1954
Isla Cedros, Baja Calif., to Puerto Parker, Costa Rica

Colpomenia sinuosa (Roth) Derbès & Solier f. *sinuosa*

Taylor, 1945; Coe, 1932; Dawson, 1954, 1957, 1959, 1959*c*; Scagel, 1957; Dawson, Neushul, Wildman, 1960
Yakutat Bay, Alaska, to Puerto Parker, Costa Rica; Clipperton I.; Galapagos Arch.

Colpomenia sinuosa f. *expansa* Saunders

Setchell & Gardner, 1925
Avalon, Santa Catalina I., Calif.

Colpomenia sinuosa f. *tuberculata* (Saunders) Setchell & Gardner

Dawson, 1954; Scagel, 1957; Dawson, 1959
Unalaska, Alaska, to southern Baja Calif.; Gulf of Calif.

Hydroclathrus clathratus (Bory) Howe

Coe, 1932; Dawson, 1954; Taylor, 1945; Dawson, 1959
La Jolla, Calif. to Scammon Lagoon, Baja Calif.; southern Gulf of Calif.; Guayas, Ecuador

Rosenvingea intricata (J. Agardh) Børgesen

Dawson, 1954; Taylor, 1945; Dawson, 1959
Bahía Tepoca, Sonora, to Acapulco, Guerrero; Revillagigedo Arch.; Guayas, Ecuador

Rosenvingea orientalis (J. Agardh) Børgesen

Dawson, 1960*a*
Bahía Potrero Grande, Costa Rica

FAM. CHNOOSPORACEAE

Chnoospora implexa Hering, in J. Agardh

Dawson, 1957, 1957*b*, 1959, 1959*b*
Southern Gulf of Calif.; Golfo de Nicoya, Costa Rica; Clipperton I.

Chnoospora minima (Hering) Papenfuss

Papenfuss, 1956; Dawson, 1954, 1954*c* (both as *C. pacifica*)
La Paz, Gulf of Calif., to San Agustín, Oaxaca; Isla San Benedicto, Revillagigedo Arch.

Chnoospora pannosa J. Agardh

Dawson, 1954
Isla Guadalupe, Baja Calif.

FAM. DICTYOSIPHONACEAE

Coilodesme bulligera Stroemfelt

Okamura, 1933; Scagel, 1957
Aleutian Islands to Coos Bay, Oreg.

Coilodesme californica (Ruprecht) Kjellman

Scagel, 1957; Dawson, Neushul, Wildman, 1960, 1960*a*
Queen Charlotte Str., British Columbia, to central Baja Calif.

Coilodesme corrugata Setchell & Gardner

Setchell & Gardner, 1925
Santa Catalina I., Calif.

Coilodesme cystoseirae (Ruprecht) Setchell & Gardner

Setchell & Gardner, 1925
Kukak Bay; Yakutat Bay, Alaska

Coilodesme polygnampta Setchell & Gardner

Setchell & Gardner, 1925
Amaknak I.; Unalaska, Alaska

Coilodesme rigida Setchell & Gardner

Setchell & Gardner, 1925; Dawson, 1959*c*; Dawson, Neushul, Wildman, 1960, 1960*a*
Redondo, Calif., to Bahía Tortuga, Baja Calif.

Coilodesme sitchensis Setchell & Gardner

Setchell & Gardner, 1925
Sitka, Alaska

Dictyosiphon foeniculaceus (Hudson) Greville

Scagel, 1957
Bering Sea to Puget Sound, Wash.

Dictyosiphon hippuroides (Lyngbye) Kützing

Setchell & Gardner, 1925
Bering Sea to Unalaska, Alaska

Dictyosiphon hispidus Kjellman

Setchell & Gardner, 1925
Orca, Alaska

Dictyosiphon sinicola Gardner

Scagel, 1957
Southern British Columbia to northern Wash.

Dictyosiphon tenuis Setchell & Gardner

Setchell & Gardner, 1925
Golofin Bay, Alaska

ORDER LAMINARIALES

FAM. CHORDACEAE

Chorda filum (Linnaeus) Lamouroux

Scagel, 1957
Bering Sea to Puget Sound, Wash. ?

FAM. LAMINARIACEAE

Laminaria complanata (Setchell & Gardner) Setchell

Scagel, 1957
Friday Harbor, Wash.

Laminaria cordata Dawson

Dawson, 1950*a*
Santa Catalina I., Calif.

Laminaria cuneifolia J. Agardh f. *cuneifolia*

Scagel, 1957
Bering Sea to Oreg.

Laminaria cuneifolia f. *amplissima* Setchell & Gardner

Scagel, 1957
Sitka, Alaska, to Cape Flattery, Wash.

Laminaria cuneifolia f. *angusta* Setchell & Gardner

Scagel, 1957
Southern British Columbia to northern Wash.

Laminaria cuneifolia f. *subsimplex* Setchell & Gardner

Scagel, 1957
Southern British Columbia to northern Wash.

Laminaria dentigera Kjellman

Setchell & Gardner, 1925
Aleutian Islands, Alaska

Laminaria ephemera Setchell

Scagel, 1957
Southern British Columbia to Oreg.; Monterey Peninsula, Calif.

Laminaria farlowii Setchell

Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Santa Cruz, Calif., to Bahía del Rosario, Baja Calif.

Laminaria longipes Bory

Okamura, 1933; Setchell & Gardner, 1925
Aleutian Islands, Alaska

Laminara personata Setchell & Gardner

Setchell & Gardner, 1925
Yakutat Bay to Sitka, Alaska

Laminaria platymeris De la Pylaie

Scagel, 1957
Bering Sea to northern Wash.

Laminaria saccharina (Linnaeus) Lamouroux f. *saccharina*

Scagel, 1957
Alaska to Coos Bay, Oreg.

Laminaria saccharina f. *linearis* J. Agardh

Scagel, 1957
Unga, Alaska, to Puget Sound, Wash.

Laminaria saccharina f. *membranacea* J. Agardh

Scagel, 1957
Alaska to Coos Bay, Oreg.

Laminaria setchellii Silva

Scagel, 1957
Northern British Columbia to southern Calif. Channel Islands

Laminaria sinclairii (Harvey in Hooker f.) Farlow, Anderson & Eaton

Scagel, 1957; Dawson, 1958, 1959*c*
Southern British Columbia to Ventura Co., Calif.

Pleurophycus gardneri Setchell & Saunders

Scagel, 1957
Yakutat Bay, Alaska, to Coos Bay, Oreg.

Cyamathere triplicata (Postels & Ruprecht) J. Agardh

Scagel, 1957
Bering Sea to northern Wash.

Costaria costata (Turner) Saunders

Scagel, 1957
Shumagin I., Alaska, to San Pedro, Calif.

Costaria mertensii J. Agardh

Scagel, 1957
Bering Sea to Monterey, Calif.

Thalassiophyllum clathrus (Gmelin) Postels & Ruprecht

Okamura, 1933; Scagel, 1957
Bering Sea to Straits of Juan de Fuca ?

Agarum cribrosum (Mertens) Bory

Scagel, 1957
Bering Sea to northern Wash.

Agarum fimbriatum Harvey

Scagel, 1957; Dawson, Neushul & Wildman, 1960
Puget Sound, Wash., to southern Calif. Channel Islands

Hedophyllum bongardianum (Postels & Ruprecht) Yendo

Miyabe & Nagai, 1932; Scagel, 1957 (as *Hedophyllum subsessile*)
Bering Sea to Coos Bay, Oreg.

Hedophyllum sessile (C. Agardh) Setchell

Okamura, 1933; Scagel, 1957
Aleutian Islands to Point Sur, Calif.

Arthrothamnus bifidus (Gmelin) J. Agardh

Setchell & Gardner, 1925
Aleutian Islands, Alaska

FAM. LESSONIACEAE

Dictyoneurum californicum Ruprecht

Scagel, 1957
Vancouver I., British Columbia ?, to San Luis Obispo Co., Calif.

Dictyoneuropsis reticulata (Saunders) G. M. Smith

Smith, 1944; Silva, 1957
Fort Ross; Monterey Peninsula, Calif.; northern Channel Islands

Nereocystis luetkeana (Mertens) Postels & Ruprecht

Scagel, 1957
Shumagin I., Alaska, to San Luis Obispo Co., Calif. (drift only to Santa Barbara)

Postelsia palmaeformis Ruprecht

Scagel, 1957
Hope I., British Columbia to San Luis Obispo Co., Calif.

Macrocystis integrifolia Bory

Womersley, 1954; Scagel, 1957
Sitka, Alaska, to Carmel, Calif.

Macrocystis pyrifera (Linnaeus) C. Agardh

Doty, 1947; Dawson, 1954, 1957, 1959*c*; North, 1959; Dawson, Neushul & Wildman, 1960
Sitka, Alaska, to Punta San Hipólito, Baja Calif., and sporadically to Isla Magdalena; Rocas Alijos

Pelagophycus porra (Leman) Setchell

Dawson, 1954; Dawson, Neushul & Wildman, 1960
Point Conception, Calif., to Islas San Benito, Baja Calif.

Lessoniopsis littoralis (Farlow & Setchell ex Tilden) Reinke

Scagel, 1957
Sitka, Alaska, to Carmel, Calif.

FAM. ALARIACEAE

Pterygophora californica Ruprecht

Dawson, 1954; Scagel, 1957
Southern British Columbia to Bahía del Rosario, Baja Calif.

Alaria dolichorhachis Kjellman

Okamura, 1933; Setchell & Gardner, 1925
Aleutian Islands, Alaska

Alaria fistulosa Postels & Ruprecht f. *fistulosa*

Okamura, 1933; Setchell & Gardner, 1925
Bering Sea to Wrangel, Alaska

Alaria fistulosa f. *platyphylla* Setchell

Setchell & Gardner, 1925
Bering Sea to southeastern Alaska

Alaria fistulosa f. *stenopylla* Setchell

Setchell & Gardner, 1925
Bering Sea to southeastern Alaska

Alaria lanceolata Kjellman

Setchell & Gardner, 1925
Bering Sea to Sitka, Alaska

Alaria marginata Postels & Ruprecht

Scagel, 1957
Northern British Columbia to Carmel, Calif.

Alaria nana Schrader

Scagel, 1957
Hope I., British Columbia to Carmel, Calif.

Alaria pylaii (Bory) Greville

Setchell & Gardner, 1925
Prince William Sound to Kodiak I., Alaska

Alaria tenuifolia Setchell f. *tenuifolia*

Okamura, 1933; Setchell & Gardner, 1925
Bering Sea to northern Wash.

Alaria tenuifolia f. *amplior* Setchell & Gardner

Scagel, 1957
Southern British Columbia to northern Wash.

Alaria valida Kjellman & Setchell f. *valida*

Scagel, 1957
Unga, Alaska, to Puget Sound, Wash.

Alaria valida f. *longipes* Setchell & Gardner

Scagel, 1957
Queen Charlotte Sound, British Columbia, to northern Wash.

Eisenia arborea Areschoug

Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Kyuquot Sound, Vancouver I., British Columbia; Redondo, Calif. to Isla Magdalena, Baja Calif.

Eisenia desmarestioides Setchell & Gardner

Dawson, 1954
Isla Guadalupe, Baja Calif.

Eisenia galapagensis Taylor

Taylor, 1945
Galapagos Arch.

Eisenia masonii Setchell & Gardner

Dawson, 1954
Isla Guadalupe, Baja Calif.

Egregia laevigata Setchell subsp. *laevigata*

Coe, 1932; Dawson, 1954, 1957 (as *E. australis* Hollenberg ms.), 1959*c*; Dawson, Neushul & Wildman, 1960; Silva, 1957
Goleta, Calif., to Punta San Eugenio, Baja Calif.; Rocas Alijos

Egregia laevigata subsp. *borealis* (Setchell) Silva

Silva, 1957
Santa Cruz to Gaviota, Calif.

Egregia menziesii (Turner) Areschoug subsp. *menziesii*

Scagel, 1957
Northern British Columbia to Point Conception, Calif.

Egregia menziesii subsp. *insularis* Silva

Silva, 1957
Northern Channel Islands, Calif.

ORDER FUCALES

FAM. FUCACEAE

Fucus distichus Linnaeus, emend Powell

Powell, 1957 (All species and subspecies of *Fucus* heretofore recognized from Pacific North America, with the exception of *F. parksii*, are considered by Powell as variants of *F. distichus*. Under subspecies *edentatus* he places *F. edentatus* De la Pylaie, *F. furcatus* C. Ag. (*F. gardneri* Silva), *F. nitens* Gard. and *F. evanescens* C. Ag., in part. Under subsp. *evanescens* he places *F. evanescens* C. Ag., in part. He considers *F. membranaceus* Gard. not sufficiently distinct even for subspecies status. See Dawson, 1946*a*, for a listing of the described forms, also Scagel, 1957 (various northern forms); Dawson, 1958 (as *F. furcatus*), 1959*c* (as *F. furcatus*)
Bering Sea to Government Point, Calif.

Fucus parksii Gardner

Gardner, 1940
Humbolt Bay; Eureka, Calif.

Pelvetia fastigiata (J. Agardh) G. De Toni f. *fastigiata*

Dawson, 1954; Scagel, 1957; Dawson, 1959*c*
Horswell Channel, British Columbia; Coos Bay, Oreg., to Punta Baja, Baja Calif.

Pelvetia fastigiata f. *gracilis* Setchell & Gardner

Smith, 1944; Dawson, 1954
Monterey Peninsula; Channel Islands, Calif.; northern Baja Calif.

Pelvetiopsis arborescens Gardner

Gardner, 1940
Point Carmel, Calif.

Pelvetiopsis limitata (Setchell) Gardner f. *limitata*

Scagel, 1957
Hope I., British Columbia, to Carmel, Calif.

Pelvetiopsis limitata f. *lata* Gardner

Smith, 1944
Tomales Point to Monterey, Calif.

Hesperophycus harveyanus (Decaisne) Setchell & Gardner

Dawson, 1954, 1959*c*
Santa Cruz, Calif., to Islas San Benito, Baja Calif.

FAM. SARGASSACEAE

Cystophora brandegeei (Setchell & Gardner) Dawson

Dawson, 1954, 1945*c*
La Jolla, Calif., to Isla Guadalupe, Baja Calif.

Cystophora galapagensis (Piccone & Grunow in Piccone) comb. nov.

Taylor, 1945 (as *Blossevillea galapagensis*); Piccone, 1886: 40 (as *Fucodium galapagense*)
Galapagos Arch.

Cystoseira geminata C. Agardh

Scagel, 1957
Bering Sea to northern Wash.

Cystoseira neglecta Setchell & Gardner

Dawson, 1954
Santa Catalina I., Calif., to Desembarcadero de Miller, Baja Calif.

Cystoseira osmundacea (Menzies) C. Agardh

Doty, 1947; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960.
Seaside, Oreg., to Punta Abreojos, Baja Calif.

Cystoseira setchellii Gardner

Setchell & Gardner, 1925
Redondo to San Diego, Calif.

Halidrys dioica Gardner

Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Redondo, Calif., to Isla Asunción, Baja Calif.

Sargassum acinacifolium Setchell & Gardner

Dawson, 1954
Puerto Libertad to Guaymas, Sonora

Sargassum agardhianum Farlow

Dawson, 1954, 1959*c*, 1960*a*; Dawson, Neushul & Wildman, 1960
Point Dume, Calif., to Punta Eugenio, Baja Calif.

Sargassum albemarlense Taylor

Taylor, 1945; Dawson, 1957
Galapagos Arch.

Sargassum brandegeei Setchell & Gardner

Taylor, 1945; Dawson, 1954, 1959
Puerto Libertad to Isla San Pedro Nolasco, Gulf of Calif.; Galapagos Arch.

Sargassum camouii Dawson

Dawson, 1954
Bahía Viscaino, Baja Calif.; east central Gulf of Calif.

Sargassum ecuadoreanum Taylor

Taylor, 1945
Vicinity of Guayas, Ecuador

Sargassum galapagense Grunow

Taylor, 1945
Galapagos Arch.

Sargassum herporhizum Setchell & Gardner

Dawson, 1954
Isla George; Isla San Pedro Mártir, Gulf of Calif.

Sargassum horridum Setchell & Gardner

Dawson, 1954, 1959
Southern Gulf of Calif.

Sargassum howellii Setchell & Gardner

Dawson, 1954
Revillagigedo Arch.

Sargassum johnstonii Setchell & Gardner f. *johnstonii*

Dawson, 1954
Punta Peñasco to Bahía Agua Verde, Gulf of Calif.

Sargassum johnstonii f. *gracile* Setchell & Gardner

Dawson, 1954
Punta Peñasco to Guaymas, Gulf of Calif.

Sargassum lapazeanum Setchell & Gardner

Dawson, 1954
Guaymas to La Paz, Gulf of Calif.

Sargassum liebmannii J. Agardh var. *liebmannii*

Dawson, 1954, 1957*b*
San Jose del Cabo, Baja Calif., to Bahía Honda, Panamá

Sargassum liebmannii var. *nicoyana* Grunow

Dawson, 1957*b*
Golfo de Nicoya, Costa Rica

Sargassum macdougalii Dawson

Dawson, 1954, 1959
Central and northern Gulf of Calif.

Sargassum muticum (Yendo) Fensholt

Scagel, 1957
Nanaimo, British Columbia, to Coos Bay, Oreg.

Sargassum pacificum Bory f. *pacificum*

Taylor, 1945; Dawson, 1957
Galapagos Arch.

Sargassum pacificum f. *congestum* Setchell

Taylor, 1945
Galapagos Arch.

Sargassum pacificum f. *rigidiusculum* (Grunow) Setchell

Taylor, 1945
Galapagos Arch.

Sargassum pacificum f. *megaphyllum* Taylor

Taylor, 1945
Galapagos Arch.

Sargassum palmeri Grunow

Dawson, 1954
Santa Cruz ?; Santa Catalina I., Calif., to Islas San Benito, Baja Calif.

Sargassum setifolium (Grunow) Setchell

Taylor, 1945; Dawson, 1957
Galapagos Arch.

Sargassum sinicola Setchell & Gardner

Dawson, 1954, 1959
Punta Peñasco to La Paz, Gulf of Calif.; Isla Guadalupe, Baja Calif.

Sargassum skottsbergii Sjoestedt, prox.

Taylor, 1945
Salinas, Ecuador

Sargassum sonorense Dawson

Dawson, 1960*a*
Northern Gulf of Calif.

Sargassum templetonii Setchell

Taylor, 1945; Dawson, Neushul & Wildman, 1960*a*
Isla Magdalena, Baja Calif.; Galapagos Arch.

Sargassum vizcainense Dawson

Dawson, 1954; Dawson, Neushul & Wildman, 1960*a*
Bahía Vizcaino and Isla Cedros to Punta Pequeña, Baja Calif.

Sargassum zacae Setchell

Taylor, 1945
Galapagos Arch.

PHYLUM **RHODOPHYCOPHYTA**

CLASS **RHODOPHYCEAE**

SUBCLASS **BANGIOPHYCIDAE**

ORDER **GONIOTRICHALES**

FAM. GONIOTRICHACEAE

Goniotrichum cornu-cervi (Reinsch) Hauck

Scagel, 1957
Friday Harbor, Wash.; Santa Cruz I., Calif.

Goniotrichum elegans (Chauvin) Zanardini

Taylor, 1945 (as *G. alsidii*); Dawson, 1954, 1957*b*; Scagel, 1957
Friday Harbor, Wash., to Isla Gorgona, Colombia

Goniotrichopsis sublittoralis G. M. Smith

Smith, 1944
Monterey, Calif.

ORDER **BANGIALES**

FAM. ERYTHROPELTIDACEAE

Smithora naiadum (Anderson) Hollenberg

Hollenberg, 1959; Dawson, Neushul & Wildman, 1960; Dawson, 1949*a* (as *Porphyra naiadum*); Scagel, 1957 (as *Porphyra naiadum*); Dawson, 1954 (as *Porphyra naiadum* var. *australis*), 1959*c* (as *Porphyra naiadum*)
Northern British Columbia to Isla Magdalena, Baja Calif.

Erythropeltis discigera (Berthold) Schmitz

Dawson, 1954
Isla Tiburón, Gulf of Calif.

Erythrotrichia ascendens Dawson

Dawson, 1954
Cabo Pulmo, southern Gulf of Calif.

Erythrotrichia biseriata Tanaka

Dawson, 1954, 1954*c*
Islas San Benito; Punta Abreojos, Baja Calif.; Gulf of Calif. to Mazatlán, Sinaloa; Isla San Benedicto, Revillagigedo Arch.

Erythrotrichia boryana (Montagne) Berthold

Dawson, 1954
Punta Baja to Bahía Asunción, Baja Calif.

Erythrotrichia californica Kylin

Smith, 1944; Dawson, 1954
Monterey, Calif.; Ensenada, Baja Calif.; Isla Tiburón, Gulf of Calif.

Erythrotrichia carnea (Dillwyn) J. Agardh

Smith, 1944; Dawson, 1954, 1957*b*, 1959*b*
Monterey, Calif., to Golfo Dulce, Costa Rica; Clipperton I.

Erythrotrichia ciliaris (Carmichael) Batters

Dawson, 1954
Punta Baja; Isla Cedros, Baja Calif.

Erythrotrichia kylinii Gardner

Scagel, 1957
Bering Sea to Puget Sound, Wash.

Erythrotrichia parksii Gardner var. *parksii*

Gardner, 1927
Eureka, Calif.

Erythrotrichia parksii var. *minor* Gardner

Scagel, 1957
Southern British Columbia to northern Wash.

Erythrotrichia polymorpha Howe

Taylor, 1945
Galapagos Arch.

Erythrotrichia porphyroides Gardner

Gardner, 1927
San Francisco, Calif.

Erythrotrichia pulvinata Gardner

Doty, 1947; Hollenberg, 1948; Dawson, 1954
Middle Bay, Oreg., to Bahía Asunción, Baja Calif.

Erythrotrichia tetraseriata Gardner

Dawson, 1954
San Pedro, Calif.; Isla Magdalena, Baja Calif.

Erythrotrichia welwitschii (Ruprecht) Batters

Doty, 1947
South Bay, Oreg.; Monterey, Calif.

Erythrocladia ectozoica Dawson

Dawson, 1954
Scammon Lagoon, Baja Calif.

Erythrocladia irregularis Rosenvinge

Dawson, 1954; Scagel, 1957
Northern Wash. to Monterey, Calif.; Isla Turner, Gulf of Calif.

Erythrocladia subintegra Rosenvinge

Dawson, 1954; Scagel, 1957
Northern Wash. to northern Baja Calif.; Gulf of Calif.

FAM. BANGIACEAE

Bangia enteromorphoides Dawson

Dawson, 1954
Mazatlán, Sinaloa

Bangia fuscopurpurea (Dillwyn) Lyngbye

Dawson, 1954, 1959*c*; Scagel, 1957
Northern British Columbia to Costa Rica

Bangia maxima Gardner

Gardner, 1927
Bolinas, Calif.

Bangia tenuis Gardner

Scagel, 1957
Orcas I., Wash.

Bangia vermicularis Harvey

Sanborn & Doty, 1946; Doty, 1947
Coos Bay, Oreg., to Carmel, Calif.

Porphyra abyssicola Kjellman

Scagel, 1957
Southern British Columbia to northern Wash.

Porphyra amplissima (Kjellman) Setchell & Hus

Scagel, 1957
Amaknak I., Alaska, to northern Wash.

Porphyra hollenbergii Dawson

Dawson, 1954, 1959
Southern Gulf of Calif.

Porphyra laciniata (Lightfoot) C. Agardh

Setchell & Gardner, 1903
Amaknak I. to Sitka, Alaska

Porphyra lanceolata (Setchell & Hus) G. M. Smith

Scagel, 1957
Chehalis Bay, Wash. to Carmel, Calif.

Porphyra miniata f. *cuneiformis* Setchell & Hus

Scagel, 1957
Gulf of Alaska to Monterey, Calif.

Porphyra nereocystis Anderson

Scagel, 1957
Uyak Bay, Alaska, to San Pedro, Calif.? (probably to San Luis Obispo Co.)

Porphyra occidentalis Setchell & Hus

Sanborn & Doty, 1946; Doty, 1947
Coos Bay, Oreg.; Carmel Bay, Calif.

Porphyra pendula Dawson

Dawson, 1954
Isla Partida; Isla Patos, Gulf of Calif.

Porphyra perforata J. Agardh f. *perforata*

Okamura, 1933; Dawson, 1954, 1959*c*; Scagel, 1957
Aleutian Islands, Alaska, to Isla Magdalena, Baja Calif.

Porphyra perforata f. *segregata* Setchell & Hus

Scagel, 1957
Southern British Columbia to northern Calif.

Porphyra pulchra Hollenberg

Smith, 1944
Santa Cruz to Monterey, Calif.

Porphyra schizophylla Hollenberg

Doty, 1947
Harris State Park; Otter Point, Oreg.; Pescadero Point, Calif.

Porphyra thuretii Setchell & Dawson, in Dawson

Doty, 1947; Dawson, 1954, 1959*c*
Chetco Cove, Oreg., to Isla Magdalena, Baja Calif.; Gulf of Calif.; Puerto Parker, Costa Rica

Porphyra tenuissima (Stroemfelt) Setchell & Hus

Setchell & Gardner, 1903
Shumagin I.; Yakutat Bay, Alaska

Porphyra umbilicalis (Linnaeus) Kützing

Scagel, 1957 (but with incorrect authorship)
St. Paul I., Alaska, to southern British Columbia

Porphyra variegata (Kjellman) Hus

Scagel, 1957
Southern British Columbia to Monterey, Calif.

Porphyrella californica Hollenberg

Hollenberg, 1945
Southern Calif.

Porphyrella gardneri Smith & Hollenberg

Hollenberg, 1945; Scagel, 1957
Northern British Columbia to Monterey, Calif.

Porphyropsis coccinea (J. Agardh) Rosenvinge

Scagel, 1957
Friday Harbor, Wash.

Conchocelis rosea Batters (probably represents a stage in the life cycle of one or more species of *Porphyra*)

Scagel, 1957
Northern Wash.

SUBCLASS FLORIDEOPHYCIDAE

ORDER NEMALIONALES

FAM. ACROCHAETIACEAE

Acrochaetium amphiroae (Drew) Papenfuss

Dawson, 1945*b* (as *Rhodochorton amphiroae*); Doty, 1947; Dawson, 1954
Oreg. to Isla Cedros, Baja Calif.

Acrochaetium angustum (Drew) Papenfuss

Papenfuss, 1945
Santa Catalina I., Calif.

Acrochaetium ascidiophilum Dawson

Dawson, 1954
Bahía San Quintín, Baja Calif.

Acrochaetium bonnemaisoniae (Batters) J. & G. Feldmann

Dawson, 1954
Punta San Quintín, Baja Calif.

Acrochaetium bornetii Papenfuss

Dawson, 1954
San Pedro, Calif.; Punta Pequeña, Baja Calif.

Acrochaetium coccineum (Drew) Papenfuss

Papenfuss, 1945
Marin Co.; San Francisco, Calif.

Acrochaetium daviesii (Dillwyn) Nägeli

Dawson, 1954; Dawson, Neushul & Wildman, 1960*a*
Carmel, Calif., to Isla Clarión, Revillagigedo Arch.

Acrochaetium densum (Drew) Papenfuss

Papenfuss, 1945
San Francisco, Calif.

Acrochaetium desmarestiae Kylin

Scagel, 1957
Northern Wash. to Oreg.

Acrochaetium dictyotae Collins

Papenfuss, 1945
San Diego Co., Calif.

Acrochaetium eastwoodae (Setchell & Gardner) Papenfuss

Dawson, 1954
Isla Clarión, Revillagigedo Arch.

Acrochaetium elegans (Drew) Papenfuss

Papenfuss, 1945
La Jolla, Calif.

Acrochaetium erythrophyllum Jao

Scagel, 1957
Port Angeles, Wash.

Acrochaetium gymnogongri (Drew) Papenfuss

Papenfuss, 1945
San Francisco, Calif.

Acrochaetium hancockii (Dawson) Papenfuss

Dawson, 1954
Isla Ángel de la Guarda, Gulf of Calif.

Acrochaetium infestans Howe & Hoyt

Dawson, 1960*a*
Puerto Culebra, Costa Rica

Acrochaetium macounii (Collins) Hamel

Scagel, 1957
Vancouver I., British Columbia, to Carmel Bay, Calif.

Acrochaetium magnificum (Drew) Papenfuss

Papenfuss, 1945
La Jolla, Calif.

Acrochaetium obscurum (Drew) Papenfuss

Papenfuss, 1945
Marin Co. to Carmel, Calif.

Acrochaetium pacificum Kylin

Dawson, 1954; Scagel, 1957; Dawson, Neushul & Wildman, 1960*a*
Northern Wash.; Oreg.; Islas San Benito, Baja Calif.; vicinity of Guaymas, Sonora

Acrochaetium penetrale (Drew) Papenfuss

Taylor, 1945; Dawson, 1954
La Jolla, Calif.; Bahía San Quintín, Baja Calif.; Puerto Parker, Costa Rica

Acrochaetium plumosum (Drew) G. M. Smith

Papenfuss, 1945; Dawson, 1954
Tomales Bay, Calif., to Bahía Asunción, Baja Calif.

Acrochaetium punctatum Dawson

Dawson, 1954
Bahía Bocochibampo, Sonora

Acrochaetium rhizoideum (Drew) Jao var. *rhizoideum*

Dawson, 1954; Scagel, 1957
Wash. to Isla Cedros, Baja Calif.

Acrochaetium rhizoideum var. *patens* (Drew) G. M. Smith

Smith, 1944
Carmel, Calif.

Acrochaetium scinaiae Dawson

Dawson, 1954
Santa Barbara I., Calif.; Gulf of Calif.

Acrochaetium simplex (Drew) Papenfuss

Papenfuss, 1945
Santa Monica, Calif.

Acrochaetium sinicolum (Dawson) Papenfuss

Dawson, 1954
Isla Turner, Gulf of Calif.

Acrochaetium spiculiphilum Dawson

Dawson, 1954
Bahía San Quintín, Baja Calif.

Acrochaetium subimmersum (Setchell & Gardner) Papenfuss

Scagel, 1957
Northern Wash. to Carmel, Calif.

Acrochaetium subseriatum Børgesen

Dawson, 1959*b*
Clipperton I.

Acrochaetium tenuissimum (Collins) Papenfuss

Papenfuss, 1945
San Pedro, Calif.

Acrochaetium thuretii var. *agama* (Rosenvinge) Dawson

Dawson, 1945*d*
San Pedro, Calif.

Acrochaetium vagum (Drew) Jao

Scagel, 1957
Northern Wash. to Moss Beach, Calif.

Acrochaetium variabile (Drew) G. M. Smith

Dawson, 1954; Scagel, 1957; Dawson, 1954*c*
Northern Wash. to Isla San Martín, Baja Calif.; Mazatlán, Sinaloa; Isla San Benedicto, Revillagigedo Arch.

Kylinia arcuata (Drew) Kylin

Dawson, 1954; Scagel, 1957
Cape Flattery, Wash., to Moss Beach, Calif.; Isla Turner, Gulf of Calif.

Kylinia crassipes (Børgesen) Kylin

Dawson, 1954
Bahía Vizcaino, Baja Calif.; Isla Rasa, Gulf of Calif. ?

Kylinia hirsuta (Drew) Kylin

Dawson, 1949; Scagel, 1957
Vancouver, British Columbia; Santa Catalina I., Calif.

Kylinia implicata (Drew) Papenfuss

Papenfuss, 1947
Moss Beach, Calif.

Kylinia microscopica (Nägeli) Kylin

Kylin, 1944; Papenfuss, 1945 (as *Chromastrum microscopicum*)
La Jolla, Calif.

Kylinia moniliformis (Rosenvinge) Kylin

Scagel, 1957
Vancouver I., British Columbia

Kylinia porphyrae (Drew) Papenfuss

Papenfuss, 1945 (as *Chromastrum porphyrae*); Dawson, 1954
San Francisco; Monterey, Calif.; Bahía San Quintín, Baja Calif.

Kylinia secundata (Lyngbye) Papenfuss

Dawson, 1954
Bahía Bocochibampo, Sonora

Kylinia seriaspora Dawson

Dawson, 1954
Isla Turner, Gulf of Calif.

Rhodochorton concrescens Drew

Papenfuss, 1945
Carmel Bay, Calif.

Rhodochorton penicilliforme (Kjellman) Rosenvinge

Scagel, 1957
Spruce I., Alaska, to San Juan Co., Wash.

Rhodochorton purpureum (Lightfoot) Rosenvinge

Dawson, 1954; Scagel, 1957
Bering Sea to Punta Eugenio, Baja Calif.

Rhodochorton tenue Kylin

Scagel, 1957
San Juan I., Wash.; Santa Cruz, Calif.

Audouinella membranacea (Magnus) Papenfuss

Scagel, 1957
San Juan Co., Calif.

FAM. HELMINTHOCLADIACEAE

Nemalion helminthoides (Velley) Batters

Dawson, 1954; Scagel, 1957; Dawson, 1959*c*, 1960*a*
Sitka, Alaska, to Isla Magdalena, Baja Calif.

Nemalion pulvinatum Grunow

Dawson, 1954
Bahía Agua Verde, Baja Calif.

Nemalion virens J. Agardh

Dawson, 1954
Cabeza Ballena, southern Baja Calif.; Pacific Mexico, probably Oaxaca

Helminthora saundersii Gardner

Smith, 1944
Monterey, Calif.

Helminthora stricta Gardner

Gardner, 1926
La Jolla, Calif.

Dermonema frappieri (Montagne & Millardet) Børgesen

Dawson, 1954, 1954*b*, 1954*c*, 1959
Isla San Benedicto, Revillagigedo Arch.; Isla Carmén, Gulf of Calif.; Mazatlán, Sinaloa

Helminthocladia californica (J. Agardh) Kylin

Dawson, 1954
Santa Barbara, Calif., to Punta Pequeña, Baja Calif.

Helminthocladia gracilis Gardner

Gardner, 1926
Santa Barbara, Calif.

Cumagloia andersonii (Farlow) Setchell & Gardner

Dawson, 1954; Scagel, 1957
Hope I., British Columbia, to Cabo Colnett, Baja Calif.

Liagora abbottae Dawson

Dawson, 1954
Punta Santa Rosalía, Baja Calif.

Liagora californica Zeh

Dawson, 1945*d*, 1954
Santa Catalina I., Calif., to Isla Guadalupe, Baja Calif.

Liagora ceranoides Lamouroux f. *ceranoides*

Taylor, 1945; Dawson, 1957*b*
Costa Rica

Liagora ceranoides f. *leprosa* (J. Agardh) Yamada

Dawson, 1954
Isla Guadalupe; Bahía Vizcaino, Baja Calif.

Liagora farinosa Lamouroux f. *farinosa*

Dawson, 1959
Southwestern Gulf of Calif.

Liagora farinosa f. *pinnatiramosa* Yamada

Dawson, 1954, 1957
Isla Guadalupe; Rocas Alijos, Baja Calif.

Liagora magniinvolucra Dawson

Dawson, 1954, 1959
Southwestern Gulf of Calif.

Liagora orientalis J. Agardh

Dawson, 1954
Bahía Vizcaino, Baja Calif.

Liagora valida Harvey

Dawson, 1957*b*
Golfo Dulce, Costa Rica

FAM. CHAETIANGIACEAE

Gloiophloea confusa Setchell

Dawson, 1954, 1959*c*, 1960*a*; Scagel, 1957; Taylor, 1945; Dawson, Neushul & Wildman, 1960; also see Levring, 1955
Vancouver I., British Columbia, to Punta María, Baja Calif.; Gulf of Calif.; Costa Rica; Galapagos Arch.

Scinaia articulata Setchell

Setchell, 1914*a*; Dawson, 1949
Santa Barbara I.; Santa Barbara, Calif.

Scinaia complanata (Collins) Cotton

Taylor, 1945
Puerto Culebra, Costa Rica; Galapagos Arch.

Scinaia johnstoniae Setchell

Taylor, 1945; Dawson, 1954; Dawson, Neushul & Wildman, 1960
Southern Calif. to Costa Rica; Gulf of Calif.; Galapagos Arch.

Scinaia latifrons Howe

Taylor, 1945; Dawson, 1954, 1953, 1960*a*
Southern Calif. to Puerto Guatulco, Oaxaca; Gulf of Calif.; Galapagos Arch.

Scinaia minima Dawson

Dawson, 1954
Isla Cedros, Baja Calif.

Scinaia setchellii Taylor

Taylor, 1945
Galapagos Arch.

Pseudoscinaia snyderae Setchell

Setchell, 1914*a*; Dawson, 1945*b*
San Pedro to San Diego, Calif.

Whidbeyella cartilaginea Setchell & Gardner

Scagel, 1957
Whidbey I., Wash.

Galaxaura angustifrons Kjellman

Taylor, 1945
Galapagos Arch.

Galaxaura arborea Kjellman

Dawson, 1954, 1959
Bahía Santa María, Baja Calif.; southern Gulf of Calif.

Galaxaura barbata Chou

Taylor, 1945
Galapagos Arch.

Galaxaura fastigiata Decaisne

Dawson, 1954, 1959
Isla Guadalupe; Bahía Vizcaino, Baja Calif.; Gulf of Calif.; Isla María Madre, Nayarit

Galaxaura filamentosa Chou

Taylor, 1945; Dawson, 1954, 1957*b*
Isla Clarión, Revillagigedo Arch.; Costa Rica; Galapagos Arch.

Galaxaura intermedia Chou

Taylor, 1945
Galapagos Arch.

Galaxaura marginata Lamouroux

Farlow, 1902
Galapagos Arch.

Galaxaura oblongata (Ellis & Solander) Lamouroux

Taylor, 1945
Esmeraldas, Ecuador

Galaxaura ramulosa Kjellman

Taylor, 1945; Dawson, 1957*b*
Golfo Dulce, Costa Rica; Isla Jicarita, Panamá

Galaxaura spathulata Kjellman

Taylor, 1945
Galapagos Arch.

Galaxaura squalida Kjellman

Taylor, 1945; Dawson, 1954
Southeasternmost Baja Calif.; Bahía Honda, Panamá

Galaxaura stupocaula Chou

Dawson, 1957*b*
Costa Rica

Galaxaura subfruticulosa Chou

Dawson, 1954
Punta Palmilla, Baja Calif. del Sur; Isla Clarión, Revillagigedo Arch.

Galaxaura veprecula Kjellman

Taylor, 1945; Dawson, 1954, 1957*b*, 1959
Southern Gulf of Calif.; Costa Rica; Galapagos, Arch.

FAM. BONNEMAISONIACEAE

Bonnemaisonia nootkana (Esper) Silva

Scagel, 1957
Northern British Columbia to Santa Rosa I., Calif.

Bonnemaisonia geniculata Gardner

Smith, 1944
Carmel Bay to Point Sur, Calif.

Bonnemaisonia hamifera Hariot

Feldmann & Feldmann, 1942; Dawson, 1954 (both as the gametophyte generation of *Trailliella intricata*); Kylin, 1941 (as *Asparagopsis hamifera*); Silva, 1957*a* (as *Bonnemaisonia intricata,* the alternate generation of *Trailliella intricata*)
Santa Rosa I., Calif., to Punta San Quintín, Baja Calif.

Trailliella intricata Batters

Scagel, 1957 (as sporophyte generation of *Bonnemaisonia*)
Northern Wash. to central Baja Calif.

Asparagopsis taxiformis (Delile) Collins & Hervey

Dawson, 1954, 1957, 1959 (as the gametophyte generation of *Falkenbergia hillebrandii*)

Isla Guadalupe; central Baja Calif.; Rocas Alijos; Revillagigedo Arch.; Gulf of Calif.; Isla Salango, Ecuador; Galapagos Arch.

Asparagopsis svedelii Taylor

Taylor, 1945

Galapagos Arch.

Falkenbergia hillebrandii (Bornet) Falkenberg

Dawson, 1954 (as the sporophyte generation of *Asparagopsis taxiformis*)

Isla Guadalupe; Bahía Vizcaino, Baja Calif.; Miramar, Nayarit; Puerto Marqués, Guerrero

ORDER GELIDIALES

FAM. GELIDIACEAE

Gelidium arborescens Gardner

Smith, 1944

Monterey to Cambria, Calif.

Gelidium cartilagineum var. *robustum* Gardner

Scagel, 1957; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960

Southern British Columbia to Isla Magdalena, Baja Calif.

Gelidium contortum Loomis

Loomis, 1960

San Francisco; Topanga, Calif.

Gelidium coronadense Dawson

Dawson, 1954

Islas Los Coronados, Baja Calif.

Gelidium coulteri Harvey

Sanborn & Doty, 1946; Doty, 1947; Dawson, 1954, 1959*c*

Coos Bay, Oreg., to Isla Magdalena, Baja Calif.

Gelidium crinale (Turner) Lamouroux var. *crinale*

Dawson, 1954, 1959*c*; Scagel, 1957; Taylor, 1945

Southern British Columbia to Isla Magdalena, Baja Calif.; Gulf of Calif.; Mazatlán, Sinaloa; Galapagos Arch.

Gelidium crinale var. *luxurians* Collins

Gardner, 1927*e*; Dawson, 1954

Southern Calif. to Punta Baja, Baja Calif.

Gelidium deciduum Dawson

Dawson, 1954

Cabeza Ballena, near San Lucas, Baja Calif.

Gelidium densum Gardner

Gardner, 1927*e*; Dawson, 1959*c*

Montecito; San Pedro, Calif.

Gelidium distichum Loomis

Loomis, 1949

Redondo, Calif.

Gelidium filicinum Bory

Taylor, 1945

Galapagos Arch.

Gelidium gardneri Loomis

Loomis, 1960

Santa Monica Bay, Calif.

Gelidium galapagense Taylor

Taylor, 1945

Galapagos Arch.

Gelidium hancockii Taylor

Taylor, 1945 (probably the *G. serrulatum* of Farlow, 1902)

Galapagos Arch.

Gelidium isabelae Taylor

Taylor, 1945

Bahía Utria, Colombia; Galapagos Arch.

Gelidium johnstonii Setchell & Gardner

Dawson, 1954, 1959

Punta Santa Rosalía; Isla Magdalena, Baja Calif.; Gulf of Calif.

Gelidium microdentatum Dawson

Dawson, 1960*a*
San Blas, Nayarit

Gelidium microphysa Setchell & Gardner

Dawson, 1954
Isla Guadalupe; Isla Cedros, Baja Calif.; northern Gulf of Calif.

Gelidium nudifrons Gardner

Dawson, 1954; Dawson, Neushul & Wildman, 1960, 1960*a*
Southern Calif. to Bahía Tortuga, Baja Calif.

Gelidium papenfussii Loomis

Dawson, 1954
San Francisco; Santa Monica, Calif.; Punta Baja; Punta Santa Rosalía, Baja Calif.

Gelidium polystichum Gardner

Dawson, 1949, 1954
San Pedro; Santa Catalina I., Calif.; Isla Guadalupe, Baja Calif.

Gelidium pulchrum Gardner

Kylin, 1941; Sanborn & Doty, 1946; Doty, 1947; Dawson, 1954, 1959*c*
Coos Bay, Oreg., to Bahía Rosario, Baja Calif.

Gelidium purpurascens Gardner

Smith, 1944; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Bolinas, Calif., to Cabo Colnett, Baja Calif.

Gelidium pusillum (Stackhouse) Le Jolis var. *pusillum*

Smith, 1944; Doty, 1947; Dawson, 1954, 1954*c*, 1957*b*, 1959
Oreg. to Panamá

Gelidium pusillum var. *cylindricum* Taylor

Taylor, 1945; Dawson, 1953
Pacific Mexico; Esmeraldas, Ecuador

Gelidium pusillum var. *pacificum* Taylor

Taylor, 1945
Galapagos Arch.

Gelidium pusillum var. *minusculum* Weber van Bosse

Dawson, 1953
Pacific Mexico

Gelidium pusillum var. *mucronatum* Dangeard

Dawson, 1953
Pacific Mexico

Gelidium pusillum var. *conchicola* Piccone & Grunow

Dawson, 1953
Pacific Mexico

Gelidium pusillum var. *pulvinatum* (C. Agardh) Feldmann

Dawson, 1953
Pacific Mexico

Gelidium ramuliferum Gardner

Gardner, 1927*e*; Dawson, 1959*c*
Santa Barbara; San Pedro, Calif.

Gelidium sclerophyllum Taylor

Taylor, 1945; Dawson, 1954, 1957*b*
Isla Clarión, Revillagigedo Arch.; southern Baja Calif. to Golfo Dulce, Costa Rica; Esmeraldas; Guayas, Ecuador

Gelidium setchellii Gardner

Gardner 1927*e*
Marin Co., Calif.

Gelidium sinicola Gardner

Doty, 1947; Smith, 1944
South Bay, Oreg.; San Francisco Bay; Monterey, Calif.

Gelidium ? sonorense Dawson

Dawson, 1954
Near Guaymas, Sonora

Gelidium undulatum Loomis

Loomis, 1960
Redondo, Calif.

Gelidium venturianum Dawson

Dawson, 1958
Mussel Shoals, Ventura Co., Calif.

Pterocladia caloglossoides (Howe) Dawson

Dawson, 1954; Dawson, Neushul & Wildman, 1960*a*; Doty, 1947 (as *Gelidium caloglossoides*); Smith, 1944 (as *Gelidium caloglossoides*)

Oreg. ?; Monterey Peninsula, Calif. ?; Southern Calif. to Isla Asunción, Baja Calif.; Barra de Navidad, Jalisco

Pterocladia complanata Loomis

Dawson, 1954

Anaheim Landing, Calif.; Punta Descanso; Punta Eugenio, Baja Calif.

Pterocladia media Dawson

Dawson, 1958

La Jolla, Calif.

Pterocladia mcnabbiana Dawson

Dawson, 1957*b*

Golfo Dulce, Costa Rica

Pterocladia musciformis Taylor

Dawson, 1957*b*, 1960*a*

Bahía Carrizal, Colima; Golfo Dulce, Costa Rica

Pterocladia parva Dawson

Dawson, 1954

San Felipe, Gulf of Calif.

Pterocladia pyramidale (Gardner) Dawson

Dawson, 1954, 1954*c*, 1957, 1959 (as probably including *Gelidium decompositum*), 1959*c*; Dawson, Neushul & Wildman, 1960

Southern Calif. to Isla Magdalena, Baja Calif.; Isla Guadalupe; Rocas Alijos; Revillagigedo Arch.; central Gulf of Calif.; Galapagos Arch.; vicinity of Guayas, Ecuador

Gelidiocolax microsphaerica Gardner

Dawson, 1954; Fan & Papenfuss, 1959

Balboa, Calif.; Punta Descanso; Isla San Martín, Baja Calif.

FAM. GELIDIELLACEAE

Gelidiella acerosa (Forsskål) Feldmann & Hamel

Dawson, 1954

Southern Gulf of Calif. to Central America

Gelidiella adnata Dawson

Dawson, 1954*c*

Isla San Benedicto, Revillagigedo Arch.

Gelidiella hancockii Dawson

Dawson, 1954, 1959, 1960*a*

Bahía Magdalena, Baja Calif.; Gulf of Calif.; Isla del Caño, Costa Rica; Isla del Rey, Panamá

Gelidiella ligulata Dawson

Dawson, 1954

Southeasternmost Baja Calif.

Gelidiella machrisiana Dawson

Dawson, 1957*b*

Golfo de Nicoya, Costa Rica

Gelidiella ? refugiensis Dawson

Dawson, 1954

Isla Ángel de la Guarda; Bahía San Carlos ?, Gulf of Calif.

Gelidiella stichidiospora Dawson

Dawson, 1954

Isla Cedros, Baja Calif.

Gelidiella pannosa (Feldmann) Feldmann & Hamel

Dawson, 1957*b* (as *G. tenuissima*)

Costa Rica

OF UNCERTAIN FAMILY POSITION

Wurdemannia miniata (Draparnaud) Feldmann & Hamel

Dawson, 1954, 1957*b*

Puerto San Carlos, Gulf of Calif. to Panamá

ORDER CRYPTONEMIALES

FAM. DUMONTIACEAE

Dudresnaya colombiana Taylor

Taylor, 1945
Isla Gorgona, Colombia

Cryptosiphonia woodii (J. Agardh) J. Agardh

Scagel, 1957; Dawson, 1959*c*
Unalaska, Alaska, to Venice, Calif.

Thuretellopsis peggiana Kylin

Scagel, 1957
Friday Harbor, Wash.

Dumontia filiformis (Lyngbye) J. Agardh

Setchell & Gardner, 1903
Alaska

Baylesia plumosa Setchell

Smith, 1944
Santa Cruz; Monterey, Calif.

Pikea californica Harvey

Dawson, 1954, Scagel, 1957
Southern British Columbia to Punta Baja, Baja Calif.

Pikea pinnata Setchell

Scagel, 1957
Northern Wash. to Coronado, Calif.

Farlowia compressa J. Agardh

Scagel, 1957
Northern Wash. to Carmel, Calif.

Farlowia mollis (Harvey & Bailey) Farlow & Setchell

Scagel, 1957; Doty, 1947 (as including *F. crassa*); Dawson, 1959*c* (as *F. crassa*)
Dixon Harbor, Alaska, to San Diego, Calif.

Dilsea californica (J. Agardh) Schmitz

Scagel, 1957
Unga I., Alaska, to San Francisco, Calif.

Dilsea integra (Kjellman) Rosenvinge

Setchell & Gardner, 1903 (as *Sarcophyllis arctica*)
Alaska

Leptocladia binghamiae J. Agardh

Setchell, 1912; Kylin, 1941; Dawson, 1954; Dawson, Neushul & Wildman, 1960; Taylor, 1945
Santa Cruz, Calif., to Isla Magdalena, Baja Calif.; Galapagos Arch.

Leptocladia conferta Setchell

Smith, 1944; Doty, 1947 (as *Pikea nootkana*)
Crescent City to Carmel Bay, Calif.

Weeksia fryeana Setchell

Scagel, 1957
Northern Wash.

Weeksia howellii Setchell & Gardner

Dawson, 1954
Isla Natividad, Baja Calif.

Weeksia reticulata Setchell

Smith, 1944; Dawson, 1945*e* (but the determination erroneous)
Monterey Peninsula, Calif.

Weeksia templetonii Setchell & Gardner

Dawson, 1954
Santa Cruz I., Calif.; Isla Cedros, Baja Calif.

Constantinea rosa-marina (Gmelin) Postels & Ruprecht

Setchell & Gardner, 1903; Setchell, 1906
Western Aleutian Islands to Sitka, Alaska

Constantinea simplex Setchell

Scagel, 1957
Northern British Columbia to Carmel, Calif.

Constantinea subulifera Setchell

Scagel, 1957
Northern British Columbia to northern Wash.

FAM. RHIZOPHYLLIDACEAE

Ochtodes crockeri Setchell & Gardner

Taylor, 1945; Dawson, 1957
Galapagos Arch.

FAM. GLOIOSIPHONIACEAE

Gloiosiphonia californica (Farlow) J. Agardh
Dawson, 1954; Scagel, 1957; Dawson, 1958
Sitka, Alaska, to Punta Baja, Baja Calif.

Gloiosiphonia capillaris (Hudson) Carmichael
Scagel, 1957
Southern British Columbia

Gloiosiphonia verticillaris Farlow
Scagel, 1957
Sitka, Alaska, to Carmel Bay, Calif.

FAM. ENDOCLADIACEAE

Gloiopeltis furcata (Postels & Ruprecht) J. Agardh
Scagel, 1957
Aleutian Islands, Alaska, to Oreg.

Gloiopeltis minuta Kylin
Kylin, 1941; Dawson, 1954
Santa Catalina I., Calif.; Islas San Benito; Punta Eugenio, Baja Calif.

Endocladia muricata (Postels & Ruprecht) J. Agardh
Okamura, 1933; Dawson, 1954, 1959*c*; Scagel, 1957
Aleutian Islands, Alaska, to Punta Santo Tomás, Baja Calif.

FAM. SQUAMARIACEAE

Ethelia mexicana Dawson
Dawson, 1954
Acapulco, Guerrero

Peyssonelia clarionensis Taylor
Taylor, 1945; Dawson, 1954
Isla Clarión, Revillagigedo Arch.; Galapagos Arch.

Peyssonelia conchicola Piccone & Grunow
Dawson, 1954, 1957*b*
Bahía San Lucas, Baja Calif.; Golfo Dulce, Costa Rica

Peyssonelia guadalupensis Dawson
Dawson, 1954
Isla Guadalupe, Baja Calif.

Peyssonelia mexicana Dawson
Dawson, 1954
Cabo Colnett, Baja Calif.; Acapulco, Guerrero

Peyssonelia pacifica Kylin
Dawson, 1954; Scagel, 1957
San Juan I., Wash., to Isla Cedros, Baja Calif.; Mazatlán, Sinaloa

Peyssonelia rubra var. *orientalis* Weber van Bosse
Dawson, 1954, 1957, 1959; Dawson, Neushul & Wildman, 1960
Southern Calif. Channel Islands to Miramar, Nayarit; Revillagigedo Arch.; Galapagos Arch.

Peyssonelia squamaria (Gmelin) Decaisne
Dawson, 1954
San Jose del Cabo, Baja Calif.

Cruoriella dubyi (Crouan & Crouan) Schmitz
Dawson, 1954, 1959*c*, 1960*a*
La Jolla, Calif., to Isla Brincanco, Panamá

Cruoriella fissurata Dawson
Dawson, 1954, 1957*b*, 1960*a*
Guaymas, Sonora, to Isla del Rey, Panamá

Cruoriella hancockii Dawson
Dawson, 1954, 1960*a*
Islas San Benito, Baja Calif., to Bahía Santiago, Colima

Cruoriella magdalenae Dawson
Dawson, 1954
Punta Eugenio; Isla Magdalena, Baja Calif.

Rhododermis elegans Crouan
Smith, 1944; Hollenberg, 1948
Marin Co. to Monterey, Calif.

Rhododermis georgii (Batters) Collins
Doty, 1947
Cape Arago, Oreg. ?

Asymmetria expansa (Setchell & Gardner) Setchell & Gardner
Smith, 1944
Monterey, Calif.

FAM. HILDENBRANDIACEAE

Hildenbrandia canariensis var. *dawsonii* Ardré
Ardré, 1959; Dawson, 1954 (as *H. prototypus* var. *kerguelensis*); Dawson, Neushul & Wildman, 1960*a*
Central Baja Calif.

Hildenbrandia galapagensis Setchell & Gardner
Setchell & Gardner, 1937
Galapagos Arch.

Hildenbrandia occidentalis Setchell
Taylor, 1945; Scagel, 1957; Dawson, Neushul & Wildman, 1960*a*
Northern British Columbia to Isla San Gerónimo, Baja Calif.; Galapagos Arch.

Hildenbrandia prototypus Nardo
Taylor, 1945; Dawson, 1954, 1954*c*, 1957*b*, 1959, 1959*c*; Scagel, 1957 (in part as *H. rosea*)
Alaska to Panamá; Galapagos Arch.

FAM. CORALLINACEAE

Archeolithothamnium crosslandi Lemoine
Taylor, 1945
Galapagos Arch.

Archaeolithothamnium howei Lemoine
Lemoine, 1929; Dawson, 1960*a*
Isla Coiba, Panamá

Archaeolithothamnium zonatosporum Foslie
Foslie, 1906; Dawson, 1960*a*
Long Beach, Calif. ?

Sporolithon pacificum Dawson
Dawson, 1960*a*
Isla del Caño, Costa Rica

Melobesia galapagensis (Foslie) Taylor
Taylor, 1945
Galapagos Arch.

Melobesia marginata Setchell & Foslie
Scagel, 1957; Dawson, 1959*c*, 1960
Southern British Columbia to Bahía Vizcaino, Baja Calif.; southern Gulf of Calif.; Revillagigedo Arch.; Costa Rica

Melobesia mediocris (Foslie) Setchell & Mason
Scagel, 1957; Dawson, 1959*c*, 1960; Dawson, Neushul & Wildman, 1960
Northern British Columbia to Isla Magdalena, Baja Calif.

Melobesia membranacea (Esper) Lamouroux
Dawson, 1960
Cabeza Ballena, Baja Calif.; Isla San Benedicto, Revillagigedo Arch.

Melobesia polystromatica Dawson
Dawson, 1960
Bahía Tenacatita, Jalisco

Lithothamnium aculeiferum L. Mason
Dawson, 1960
Duxbury Reef, Calif., to Scammon Lagoon, Baja Calif.

Lithothamnium australe (Foslie) Foslie
Dawson, 1960
Isla Guadalupe, Baja Calif., to Bahía Honda, Panamá. Gulf of Calif.; Revillagigedo Arch.

? *Lithothamnium bisporum* Foslie
Dawson, 1949
Santa Catalina I., Calif.

Lithothamnium californicum Foslie
Scagel, 1957; Dawson, 1959*c*, 1960
Southern British Columbia to Isla Magdalena, Baja Calif.

Lithothamnium cottoni Lemoine
Taylor, 1945
Galapagos Arch.

Lithothamnium fruticulosum (Kützing) Foslie
Dawson, 1960; Dawson & Beaudette, 1960
Bodega Bay, Calif., to Bahía Uvita, Costa Rica; Islas Revillagigedos; southern Gulf of Calif.

Lithothamnium giganteum L. Mason

Dawson, 1960; Dawson, Neushul & Wildman, 1960
Southern Calif. to central Baja Calif.; Bahía Petatlán, Guerrero; Corinto, Nicaragua ?

Lithothamnium guadalupensis Dawson

Dawson, 1960
Isla Guadalupe, Baja Calif.

Lithothamnium heteromorphum (Foslie) Foslie

Dawson, 1957*b*
Golfo de Nicoya, Costa Rica ?

? *Lithothamnium laeve* (Strömfelt) Foslie

Dawson, 1960
Vicinity of Isla Cedros, Baja Calif.

Lithothamnium lamellatum Setchell & Foslie

Smith, 1944; Doty, 1947; Dawson, 1960; Dawson, Neushul & Wildman, 1960
Oreg. to central Baja Calif.

Lithothamnium lenormandii (Areschoug) Foslie

Dawson, 1960
Throughout Pacific Baja Calif.; northern Gulf of Calif.; Bahía Santiago, Colima; Puerto Guatulco, Oaxaca

Lithothamnium montereyicum Foslie

Smith, 1944; Dawson, 1949; Mason, 1953; Dawson, 1960 (as possibly a form of *L. australe*)
Monterey; Anacapa I., Calif.

Lithothamnium muricatum (Foslie) G. De Toni

Scagel, 1957
Port Renfrew, British Columbia

Lithothamnium pacificum (Foslie) Foslie

Scagel, 1957; Dawson, 1960; Taylor, 1945
Vancouver I., British Columbia, to La Jolla, Calif.; Isla Grande, Guerrero ?; Galapagos Arch. ?

Lithothamnium phymatodeum Foslie

Scagel, 1957
Whidbey I., Wash., to Pacific Grove, Calif.

Lithothamnium pocillum Lemoine

Taylor, 1945
Galapagos Arch.

Lithothamnium volcanum Dawson

Dawson, 1960
Santa Cruz I., Calif.; Cortez Bank; Isla Magdalena, Baja Calif.

Polyporolithon conchatum (Setchell & Foslie) L. Mason

Scagel, 1957
Southern British Columbia to Cambria, Calif.

Polyporolithon parcum (Setchell & Foslie) L. Mason

Scagel, 1957
San Juan I., Wash., to Carmel, Calif.

Polyporolithon reclinatum (Foslie) L. Mason

Scagel, 1957
Vancouver I., British Columbia, to La Jolla, Calif.

Clathromorphum compactum (Kjellman) Foslie

Mason, 1953
St. Michael, Norton Sound, Alaska

Clathromorphum circumscriptum (Strömfelt) Foslie

Mason, 1953
Aleutian I. to Unalaska, Alaska

Hydrolithon arenicolum Dawson

Dawson, 1960
Scammon Lagoon, Baja Calif.

Hydrolithon conicum Dawson

Dawson, 1960
Isla Socorro, Revillagigedo Arch.

Hydrolithon reinboldii (Weber van Bosse & Foslie) Foslie

Dawson, 1960
Revillagigedo Arch.

Hydrolithon setchellii (Foslie) Setchell & L. Mason

Dawson, 1960
Redondo to La Jolla, Calif.; Isla Guadalupe, Baja, Calif.

Fosliella farinosa (Lamouroux) Howe

Dawson, 1960
Isla Guadalupe; southern Baja Calif.; Islas Tres Marías to Acapulco, Guerrero

Fosliella (?) *minuta* Taylor

Taylor, 1945
Bahía Honda, Panamá; Guayas, Ecuador

Fosliella paschalis (Lemoine) Setchell & Gardner

Dawson, 1959*b*, 1960
Isla Guadalupe, Baja Calif.; Isla Ildefonso; Punta Palmilla, Gulf of Calif.; Clipperton I.

Goniolithon tessellatum (Lemoine) Setchell & L. Mason

Setchell & Mason, 1943; Dawson, 1960*a*
Islas Contreras, Panamá; Galapagos Arch.

Dermatolithon canescens (Foslie) Foslie

Dawson, 1957*b*, 1960
Isla Guadalupe; Bahía Vizcaino, Baja Calif.; central Gulf of Calif.; Mazatlán, Sinaloa; Costa Rica

Dermatolithon corallinae (Crouan & Crouan) Foslie

Dawson, 1960
Santa Catalina I., Calif.; Cabeza Ballena, Baja Calif.; Bahía Tenacatita, Jalisco

Dermatolithon dispar (Foslie) Foslie

Scagel, 1957; Dawson, 1960; Dawson, Neushul & Wildman, 1960
Northern Wash. to La Jolla, Calif.; Cabeza Ballena, Baja Calif.; near Guaymas, Sonora

Dermatolithon pustulatum (Lamouroux) Foslie f. *pustulatum*

Dawson, 1957
Galapagos Arch.

Dermatolithon pustulatum f. *ascripticium* (Foslie) Foslie ex De Toni

Dawson, 1959*c* (as *D. ascripticium*), 1960; Taylor, 1945 (as *Lithophyllum mutabile*)
Coos Bay, Oreg., to Bahía Ballena, Costa Rica; Revillagigedo Arch.; Galapagos Arch.

Dermatolithon saxicolum (Lemoine) Setchell & L. Mason

Setchell & Mason, 1943
Isla Cocos, Costa Rica

Dermatolithon veleroae Dawson

Dawson, 1960
Bahía Agua Verde, Baja Calif.

Tenarea erecta Lemoine

Taylor, 1945
Galapagos Arch.

Porolithon castellum Dawson

Dawson, 1960*a*
Isla del Caño, Costa Rica

Porolithon cocosicum Lemoine

Lemoine, 1929
Isla Cocos, Costa Rica

Porolithon oncodes (Heydrich) Foslie

Dawson, 1959*b*, 1960*a*
Isla del Caño, Costa Rica; Clipperton I.

Porolithon marshallense Taylor

Dawson, 1959*b*
Clipperton I. ?

Porolithon sonorense Dawson

Dawson, 1960
Bahía Vizcaino, Baja Calif.; northern Gulf of Calif.

Mesophyllum laxum Lemoine

Taylor, 1945
Galapagos Arch.

Lithophyllum alternans Lemoine

Taylor, 1945
Galapagos Arch.

Lithophyllum amplostratum Taylor

Taylor, 1945
Galapagos Arch.

Lithophyllum (?) *coibense* Lemoine

Lemoine, 1929
Isla Coiba, Panamá

Lithophyllum complexum Lemoine

Taylor, 1945
Galapagos Arch.

Lithophyllum decipiens Foslie

Scagel, 1957; Dawson, 1957*b*, 1959*c*, 1960
Northern British Columbia to Guaymas, Sonora; Revillagigedo Arch.; Costa Rica ?; Islas Perlas, Panamá

Lithophyllum sp. aff. *L. detrusum* Foslie

Dawson, 1960
Isla Cedros, Baja Calif.

Lithophyllum diguetii (Hariot) Heydrich

Dawson, 1960
Isla Ángel de la Guarda; vicinity of La Paz, Gulf of Calif.

Lithophyllum (?) *divaricatum* Lemoine

Taylor, 1945; Dawson, 1960
Galapagos Arch.

Lithophyllum farlowii Heydrich

Taylor, 1945
Galapagos Arch.

Lithophyllum (?) *fetum* Foslie

Lemoine, 1929
Isla Cocos, Costa Rica

Lithophyllum frutescens (Foslie) Lemoine f. *frutescens*

Taylor, 1945 (possibly the *Lithothamnium calcareum* of Harvey, 1847)
Galapagos Arch.

Lithophyllum frutescens f. *galapagense* Foslie

Taylor, 1945
Galapagos Arch.

Lithophyllum grumosum (Foslie) Foslie

Smith, 1944; Doty, 1947; Dawson, 1960
Capa Arago, Oreg. ?, to Bahía Vizcaino, Baja Calif.; Isla San Benedicto, Revillagigedo Arch.

Lithophyllum hancockii Dawson

Dawson, 1960
Isla Espíritu Santo, Gulf of Calif.

Lithophyllum imitans Foslie

Dawson, 1960; Dawson, Neushul & Wildman, 1960
Moss Beach, Calif., to central Baja Calif.; Gulf of Calif.; Revillagigedo Arch.; Puerto Guatulco, Oaxaca

Lithophyllum intermedium Foslie

Taylor, 1945
Galapagos Arch.

Lithophyllum lichenare L. Mason

Scagel, 1957; Dawson, 1960
Kanaka Bay, Wash.; Farnsworth Bank, so. Calif.; Punta Banda, Baja Calif.

Lithophyllum lithophylloides Heydrich

Dawson, 1960
Gulf of Calif.; Isla Clarión, Revillagigedo Arch.

Lithophyllum (?) *lividum* Lemoine

Lemoine, 1929
Isla Cocos, Costa Rica

Lithophyllum margaritae (Hariot) Heydrich

Dawson, 1960
Vicinity of La Paz, Gulf of Calif.

Lithophyllum moluccense var. *geminostratum* Taylor

Taylor, 1945
Galapagos Arch.

Lithophyllum neofarlowii Setchell & L. Mason

Scagel, 1957; Dawson, 1960
San Juan Islands, Wash., to Cambria, Calif.; Bahía Asunción, Baja Calif.

Lithophyllum pallescens (Foslie) Heydrich

Dawson, 1960
Southern Gulf of Calif.; Islas Contreras, Panamá

Lithophyllum proboscidium Foslie var. *proboscidium*

Dawson, 1960
Bodega Bay, Calif., to Punta Santa Rosalía, Baja Calif.; vicinity of Guaymas, Sonora; Barra de Navidad, Jalisco; Acapulco, Guerrero

Lithophyllum proboscideum var. *delicatulum* Dawson

Dawson, 1960
Isla Guadalupe, Baja Calif.

Lithophyllum (?) *propinquum* var. *cocosica* Lemoine

Lemoine, 1929
Isla Cocos, Costa Rica

Lithophyllum reesei Dawson

Dawson, 1960
Punta Banda, Baja Calif.

Lithophyllum rileyi Lemoine

Taylor, 1945 (as probably equal to the *Lithothamnium crassum* of Piccone, 1889)
Galapagos Arch.

Lithophyllum samoense Foslie

Dawson, 1960
Isla Cedros, Baja Calif.

Lithophyllum sancti-georgei Lemoine

Taylor, 1945
Galapagos Arch.

Lithophyllum trichotomum (Heydrich) Lemoine

Dawson, 1957, 1960
Revillagigedo Arch.; Gulf of Calif. to Isla Jicarón, Panamá; Galapagos Arch.

Lithophyllum veleroae Dawson

Dawson, 1960
Isla Espíritu Santo; vicinity of Santa Rosalía, Gulf of Calif.

Lithophyllum whidbeyense Foslie

Scagel, 1957
Southern British Columbia to northern Wash.

Heteroderma corallinicola Dawson

Dawson, 1960
Guaymas, Sonora

Heteroderma gibbsii (Foslie & Setchell) Foslie

Dawson, 1960
Gulf of Calif.

Heteroderma lejolisii (Rosanoff) Foslie

Dawson, 1960
Bahía San Quintín, Baja Calif.

Heteroderma minutula Foslie

Dawson, 1959*b*, 1960
Isla Guadalupe; Bahía Tortuga, Baja Calif.; Puerto Guatulco, Oaxaca, to Punta Naranja, Panamá; Clipperton I.

Heteroderma nicholsii Setchell & L. Mason

Dawson, 1960
Bolinas, Calif., to Punta Abreojos, Baja Calif.

Heteroderma parvicarpa Dawson

Dawson, 1960
Scammon Lagoon, Baja Calif.

Heteroderma subtilissima (Foslie) Foslie

Dawson, 1960
Isla Guadalupe, Baja Calif.; southwesternmost Gulf of Calif.

Litholepis accola Foslie

Dawson, 1960
Isla Guadalupe, Baja Calif.; Isla Clarión, Revillagigedo Arch.

Litholepis fertilis (Lemone) Setchell & L. Mason

Setchell & Mason, 1943
Isla Coiba, Panamá

Litholepis sonorensis Dawson

Dawson, 1960
Isla Espíritu Santo, Gulf of Calif.

Choreonema thuretii (Bornet) Schmitz

Taylor, 1945; Hollenberg, 1948; Dawson, 1949, 1960
Southern Calif.; Isla Guadalupe to Bahía Vizcaino, Baja Calif.; southwestern Gulf of Calif.; Revillagigedo; Costa Rica; Galapagos Arch.

Corallina bathybentha Dawson

Dawson, 1949
Southern Calif. Channel Islands

Corallina berterii Mont. ?

Farlow, 1902; Lemoine, 1929 (as *Arthrocardia* sp.)
Galapagos Arch.

Corallina delicatulus (Doty) comb. nov.

Doty, 1947: 167 (as *Joculator delicatulus*)
Cape Arago, Oreg.

Corallina gracilis Lamouroux var. *gracilis*

Dawson, 1945*b*, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Southern Calif. to Isla Cedros, Baja Calif.

Corallina gracilis var. *verticillata* Dawson

Dawson, 1954
Santa Catalina I., Calif. ?; Isla Guadalupe, Baja Calif.

Corallina janioides Dawson

Dawson, 1954
Isla Guadalupe, Baja Calif.

Corallina officinalis Linnaeus var. *officinalis*

Taylor, 1945
Galapagos Arch.

Corallina officinalis var. *chilensis* (Harvey) Kützing

Scagel, 1957; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Northern British Columbia to Isla Magdalena, Baja Calif.; Guayas, Ecuador

Corallina pilulifera Postels & Ruprecht

Scagel, 1957 (as to Alaska records only)
Alaska

Corallina pinnatifolia (Manza) Dawson var. *pinnatifolia*

Dawson, 1954, 1958, 1959*c*; Taylor, 1945 (as *Joculator pinnatifolius*)
Carpinteria, Calif., to Isla Magdalena, Baja Calif.; Galapagos Arch.

Corallina pinnatifolia var. *digitata* Dawson

Dawson, 1954, 1959
Throughout the Gulf of Calif.

Corallina polysticha Dawson

Dawson, 1954, 1959
Santa Catalina I., Calif., to Bahía Vizcaino, Baja Calif.

Corallina vancouveriensis Yendo var. *vancouveriensis*

Dawson, 1954, 1959*c*, 1960*a*; Scagel, 1957; Dawson, Neushul & Wildman, 1960
Southern British Columbia to Punta Lobos, near Todos Santos, Baja Calif.

Corallina vancouveriensis var. *densa* Yendo

Dawson, 1953
Northern part of the range of the species.

Corallina vancouveriensis var. *aculeata* (Yendo) Dawson

Dawson, 1954.
Throughout the range of the species.

Corallina vancouveriensis var. *lycopodioides* (Taylor) Dawson

Dawson, 1954
Southern Calif. and Baja Calif.

Serraticardia macmillani (Yendo) Silva 1957

Scagel, 1957; Silva, 1957
Vancouver I., British Columbia; Fort Ross; Pescadero Point, Calif.

Cheilosporum planiusculum (Kützing) Yendo

Yendo, 1902
Port Renfrew, Vancouver I., British Columbia

Cheilosporum frondescens (Postels & Ruprecht) Yendo f. *frondescens*

Yendo, 1902
Port Renfrew, Vancouver I., British Columbia

Cheilosporum frondescens f. *maxima* Yendo

Yendo, 1902
Port Renfrew, Vancouver I., British Columbia

Cheilosporum frondescens f. *intermedia* Yendo

Yendo, 1902
Port Renfrew, Vancouver I., British Columbia

Cheilosporum frondescens f. *polymorpha* Yendo

Yendo, 1902
Port Renfrew, Vancouver I., British Columbia

Pachyarthron cretaceum (Postels & Ruprecht) Manza

Scagel, 1957
Unalaska, Alaska, to northern Wash.

Lithothrix aspergillum J. E. Gray

Dawson, 1954, 1959*c*; Scagel, 1957; Dawson, Neushul & Wildman, 1960
Vancouver I., British Columbia, to Isla Magdalena, Baja Calif.

Bossiella californica (Decaisne) Silva

Scagel, 1957
Southern British Columbia to Monterey, Calif.

Bossiella corymbifera (Manza) Silva

Scagel, 1957
Vancouver I., British Columbia, to Point Lobos, Calif.

Bossiella cooperi (Dawson & Silva) Silva

Silva, 1957
Southern Calif. Channel Islands to Punta Baja, Baja Calif.

Bossiella dichotoma (Manza) Silva var. *dichotoma*

Dawson, 1954, 1959*c*, 1960*a*; Scagel, 1957
Southern British Columbia to Punta Thurloe, Baja Calif.

Bossiella dichotoma var. *gardneri* (Manza) Dawson

Dawson, 1960*a*, 1954 (as *Bossea gardneri*); Silva, 1957 (as *Bossiella gardneri*); Dawson, 1959*c* (as *Bossiella dichotoma-gardneri* complex); Dawson, Neushul & Wildman, 1960 (as *Bossiella gardneri*)
Oreg. to Punta María, Baja Calif.

Bossiella insularis (Dawson & Silva) Silva

Silva, 1957; Dawson, 1958, 1959*c*
Southern Calif. Channel Islands; Port Hueneme, Calif., to Bahía Asunción, Baja, Calif.

Bossiella interrupta (Manza) Silva

Silva, 1957
Pacific Grove, Calif.

Bossiella ligulata (Dawson) Silva

Silva, 1957; Dawson, 1958, 1959*c*
Ventura Co., Calif.; Isla Guadalupe, Baja Calif.

Bossiella orbigniana (Decaisne) Silva

Doty, 1947 (as *Bossea orbigniana*); Dawson, 1954 (as *Bossea orbigniana*); Silva, 1957; Dawson, 1959*c*; Dawson, Neushul & Wildman, 1960
Cape Arago, Oreg. to Isla Cedros, Baja Calif.

Bossiella pachyclada (Taylor) Silva

Dawson, 1954 (as *Bossea pachyclada*); Silva, 1957
Santa Cruz I., Calif., to Isla Cedros, Baja Calif.

Bossiella plumosa (Manza) Silva

Scagel, 1957; Dawson, 1959*c*
Vancouver I., British Columbia, to Government Point, Calif.

Bossiella sagitata (Dawson & Silva) Silva

Silva, 1957; Dawson, 1958, 1959*c*
Southern Calif. Channel Islands; Port Hueneme, Calif.; Islas Coronados; Punta Eugenio, Baja Calif.

Jania adhaerens Lamouroux, prox.

Taylor, 1945
Esmeraldas, Ecuador

Jania arborescens Yendo, prox. ?

Taylor, 1945
Guayas, Ecuador

Jania capillacea Harvey

Taylor, 1945; Dawson, 1954, 1957, 1957*b*, 1959, 1959*b*
Isla Cedros, Baja Calif., to Guayas, Ecuador; Galapagos Arch.

Jania decussato-dichotoma (Yendo) Yendo

Dawson, 1954, 1959
La Jolla, Calif.; southern Gulf of Calif.

Jania longiarthra Dawson

Dawson, 1954, 1957*b*, 1959, 1959*b*
Southern Gulf of Calif.; Golfo de Nicoya, Costa Rica; Clipperton I.

Jania mexicana Taylor

Dawson, 1954
Mazatlán, Sinaloa, to Salina Cruz, Oaxaca

Jania natalensis Harvey

Dawson, 1954, 1958, 1959*c*
Lechuza Point, southern Calif., to Isla Cedros, Baja Calif.

Jania subpinnata Dawson

Dawson, 1954
Bahía de La Paz, Gulf of Calif.

Jania tenella Kützing var. *tenella*

Dawson, 1954, 1954*c*, 1957, 1957*b*, 1959, 1959*b*, 1959*c*
Southern Calif. to Costa Rica; Clipperton I.

Jania tenella var. *zacae* Dawson

Dawson, 1954, 1957*b*
Bahía Vizcaino, Baja Calif.; Isla Ildefonso, Gulf of Calif.; Costa Rica

Jania ungulata Yendo, prox.

Taylor, 1945
Galapagos Arch.; Guayas, Ecuador

Amphiroa annulata Lemoine var. *annulata*

Dawson, 1954, 1957, 1957*b*, 1959
Central Baja Calif.; Southern Gulf of Calif. to Costa Rica; Galapagos Arch.

Amphiroa annulata var. *pinnata* Dawson

Dawson, 1954, 1957*b*
Cape district, Baja Calif.; Golfo Dulce, Costa Rica?

Amphiroa beauvoisii Lamouroux

Dawson, 1957*b*
Costa Rica

Amphiroa brevianceps Dawson

Dawson, 1954; Dawson, Neushul & Wildman, 1960*a*
Punta San Hipólito, Baja Calif.; Guaymas ?, Punta Frailes ?, Gulf of Calif.; Salina Cruz, Oaxaca

Amphiroa compressa Lemoine

Taylor, 1945 (as probably equal to the *A. dilatata* of Farlow, 1902)
Galapagos Arch.

Amphiroa crossiandii Lemoine

Dawson, 1954, 1957
Rocas Alijos, Baja Calif.; Isla Socorro, Revillagigedo Arch. ?; Tangola-Tangola, Oaxaca; Isla Gorgona, Colombia

Amphiroa dimorpha Lemoine var. *dimorpha*

Dawson, 1954, 1954*c*, 1957*b*, 1959; Dawson, Neushul & Wildman, 1960, 1960*a*; Taylor, 1945
Central Pacific Baja Calif. to Central America; Gulf of Calif.; Islas Revillagigedos; Galapagos Arch.

Amphiroa dimorpha var. *digitiforme* Dawson

Dawson, 1959
Isla Carmén; Isla Ildefonso, Gulf of Calif.

Amphiroa drouetii Dawson

Dawson, 1954, 1959
Central and southern Gulf of Calif.

Amphiroa foliacea Lamouroux

Dawson, 1954
Punta Verlero, Bahía Vizcaino, Baja Calif.; Isla María Magdalena, Nayarit

Amphiroa epiphlegnoides J. Agardh, in Harvey

Harvey, 1862
Fuca Strait, Wash.

Amphiroa franciscana Taylor var. *franciscana*

Dawson, 1954
Isla Guadalupe, Baja Calif.; Isla María Magdalena, Nayarit; Esmeraldas; Guayas, Ecuador

Amphiroa franciscana var. *robusta* Dawson

Dawson, 1954
Bahía Agua Verde, Gulf of Calif.; Acapulco, Guerrero

Amphiroa galapagensis Taylor

Taylor, 1945
Galapagos Arch.

Amphiroa magdalenensis Dawson

Dawson, 1954, 1959
Isla Guadalupe; Isla Magdalena, Baja Calif.; southern Gulf of Calif.

Amphiroa mexicana Taylor

Dawson, 1954
Morro de Petatlán, Guerrero; Salina Cruz, Oaxaca

Amphiroa minutissima Taylor

Dawson, 1957*b*
Golfo Dulce, Costa Rica

Amphiroa peruana Areschoug

Taylor, 1945
Galapagos Arch.

Amphiroa subcylindrica Dawson

Dawson, 1954, 1959
Gulf of Calif.; Barra de Navidad, Jalisco

Amphiroa taylorii Dawson

Dawson, 1954, 1954*c*, 1957*b*, 1959
Revillagigedo Arch.; southern Gulf of Calif.; Isla María Magdalena, Nayarit; Costa Rica

Amphiroa tuberculosa (Postels & Ruprecht) Endlicher

Yendo, 1902
Port Renfrew, British Columbia

Amphiroa vanbosseae Lemoine

Taylor, 1945
Galapagos Arch.

Amphiroa zonata Yendo

Taylor, 1945 (as *A. peninsularis*); Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Santa Catalina I., Calif., to Isla Magdalena, Baja Calif.; Gulf of Calif.; Isla María Madre, Nayarit; Esmeraldas, Ecuador

Arthrocardia tuberculosa Weber van Bosse

Lemoine, 1929 (as equal to the *Amphiroa orbigniana* of Farlow, 1902)
Galapagos Arch.

Calliarthron chielosporioides Manza

Smith, 1944; Dawson, 1954; Dawson, Neushul & Wildman, 1960
Bolinas, Calif., to Isla Cedros, Baja Calif.

Calliarthron regenerans Manza

Scagel, 1957; Dawson, Neushul & Wildman, 1960, 1960*a*
Vancouver I., British Columbia, to Isla San Geronimo, Baja Calif.

Calliarthron setchelliae Manza

Smith, 1944
Moss Beach; Monterey, Calif.

Calliarthron schmittii Manza

Dawson, 1949; Scagel, 1957
San Juan I., Wash.; Tanner Bank; San Diego, Calif.

FAM. DERMOCORYNIDACEAE

Dermocorynus occidentalis Hollenberg

Dawson, 1954
Los Angeles Co., Calif., to Punta Banda, Baja Calif.

FAM. CRYPTONEMIACEAE

Grateloupia abreviata Kylin

Hollenberg, 1948; Dawson, 1954, 1959*c*
Southern Calif.

Grateloupia avalonae Dawson

Dawson, 1949
Catalina I., Calif.

Grateloupia dactylifera Dawson

Dawson, 1954
Near Guaymas; Isla Espíritu Santo, Gulf of Calif.

Grateloupia filicina (Lamour.) C. Agardh

Dawson, 1954
Northern Baja Calif. to San Blas, Nayarit; Gulf of Calif.

Grateloupia hancockii Dawson

Dawson, 1954
Kino; vicinity of Guaymas, Gulf of Calif.

Grateloupia howeii Setchell & Gardner

Dawson, 1954, 1959; Dawson, Neushul & Wildman, 1960
Islas San Benito to Isla Magdalena, Baja Calif.; Puerto Libertad, Sonora, to Mazatlán, Sinaloa

Grateloupia (?) *johnstonii* Setchell & Gardner

Dawson, 1954
Isla Ángel de la Guarda, Gulf of Calif.

Grateloupia maxima (Gardner) Kylin

Doty, 1947; Dawson, 1954; Dawson, Neushul & Wildman, 1960*a*
Capa Arago region, Oreg., to Isla Asunción, Baja Calif.

Grateloupia multiphylla Dawson

Dawson, 1954
Islas San Benito to Isla Magdalena, Baja Calif.

Grateloupia pinnata (Postels & Ruprecht) Setchell

Scagel, 1957
Sitka, Alaska, to northern Wash.

Grateloupia prolongata J. Agardh

Dawson, 1954, 1958, 1959, 1959*c*
Gaviota, Calif., to southern Mexico

Grateloupia schizophylla Kützing

Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960; Scagel, 1957 (as *G. californica*)
Southern British Columbia to Isla Magdalena, Baja Calif.

Grateloupia setchellii Kylin

Doty, 1947
Oreg.; Monterey, Calif.

Grateloupia (?) *squarrulosa* Setchell & Gardner

Dawson, 1944
Isla Smith, Gulf of Calif.

Grateloupia versicolor (J. Agardh) J. Agardh var. *versicolor*

Dawson, 1954, 1954*c*, 1959
Isla Magdalena, Baja Calif., to Salina Cruz, Oaxaca; southern Gulf of Calif.

Grateloupia versicolor var. *prostrata* Dawson

Dawson, 1954*c*
Isla San Benedicto, Revillagigedo Arch.

Grateloupia violacea (Setchell & Gardner) Dawson

Dawson, 1961
Northern Gulf of Calif.

Cryptonemia angustata (Setchell & Gardner) Dawson

Dawson, 1954, 1958; Dawson, Neushul & Wildman, 1960; Dawson, 1960*a*
La Jolla, Calif., to southern Baja Calif.; Bahía Tepoca, Sonora; Isla Socorro, Revillagigedo Arch.; Bahía Culebra, Costa Rica

Cryptonemia borealis Kylin

Scagel, 1957
Southern British Columbia to Oreg.

Cryptonemia decolorata Taylor

Dawson, 1954
Isla María Magdalena, Nayarit

Cryptonemia guaymasensis (Dawson) Dawson

Dawson, 1954, 1960*a*
Isla Patos to Bahía San Lucas, Gulf of Calif.; Bahía Culebra, Costa Rica

Cryptonemia obovata J. Agardh

Kylin, 1925; Scagel, 1957; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960, 1960*a*
Prince William Sound, Alaska, to Bahía Tortuga, Baja Calif.

Cryptonemia ovalifolia Kylin

Scagel, 1957
Northern Wash. to Pacific Grove, Calif.

Cryptonemia peltata Dawson, Neushul & Wildman

Dawson, Neushul & Wildman, 1960*a*
Punta Eugenio, Baja Calif.

Cryptonemia veleroae (Dawson) Dawson

Dawson, 1954
Guaymas, Sonora

Aeodes (?) *ecuadoreana* Taylor

Taylor, 1945
Galapagos Arch.

Aeodes gardneri Kylin

Scagel, 1957
Southern British Columbia to San Pedro, Calif.

Carpopeltis bushiae (Farlow) Kylin

Kylin, 1941; Dawson, 1954, 1959*c* (all as *Polyopes bushiae*); Dawson, 1959; Dawson, Neushul & Wildman, 1960; 1960*a*
Southern Calif. to Punta Abreojos, Baja Calif.

Carpopeltis clarionensis (Setchell & Gardner) Dawson

Dawson, 1954 (as *Polyopes clarionensis*); Dawson, 1959
Isla Clarión, Revillagigedo Arch.

Carpopeltis divaricata Okamura

Dawson, Neushul & Wildman, 1960*a*
Punta San Hipólito; Isla Magdalena, Baja Calif.

Carpopeltis stella-polaris Dawson

Dawson, 1959
Isla Ildefonso, Gulf of Calif.

Pachymenia saxicola Taylor

Taylor, 1945
Galapagos Arch.

Halymenia abyssicola Dawson

Dawson, 1954
Isla Partida, Gulf of Calif.

Halymenia actinophysa Howe

Dawson, 1954, 1960*a*
Throughout Gulf of Calif.; Revillagigedo Arch.; Bahía Salinas, Costa Rica

Halymenia agardhii G. DeToni

Dawson, 1954; Dawson, Neushul & Wildman, 1960*a*
Isla Asunción, Baja Calif.; Isla María Magdalena, Nayarit

Halymenia bifida Dawson

Dawson, 1954
Bahía de San Lucas, Baja Calif.

Halymenia californica Smith & Hollenberg

Dawson, 1954; Scagel, 1957
Northern Wash.; Monterey Peninsula, Calif.; Punta María, Baja Calif.

Halymenia megaspora Dawson

Dawson, 1954
Canal de San Lorenzo, Gulf of Calif.

Halymenia santamariae Taylor

Taylor, 1945
Galapagos Arch.

Halymenia utriana Taylor

Taylor, 1945
Bahía Utria, Colombia

Prionitis abbreviata Setchell & Gardner var. *abbreviata*

Taylor, 1945; Dawson, 1954 (as *Zanardinula abbreviata*), 1959
Throughout the Gulf of Calif.; Galapagos Arch.

Prionitis abbreviata var. *guaymasensis* (Dawson) Dawson

Dawson, 1954 (as *Zanardinula abbreviata* var. *guaymasensis*), 1959
Throughout the Gulf of Calif. south to Isla San Pedro Nolasco

Prionitis acroidalea (Setchell & Gardner) comb. nov.

Setchell & Gardner, 1924: 781 (as *Grateloupia acroidalea*); Dawson, 1954 (as *Zanardinula acroidalea*)
Kina, Sonora, to La Paz, Baja Calif.; Galapagos Arch.

Prionitis albemarlensis Taylor

Taylor, 1945
Galapagos Arch.

Prionitis andersoniana Eaton ex J. Agardh

Sanborn & Doty, 1946; Doty, 1947; Dawson, 1945*b*, 1954 (as *Zanardinula andersoniana*), 1959c; Dawson, Neushul & Wildman, 1960
Coos Bay, Oreg., to Punta María, Baja Calif.

Prionitis australis (J. Agardh) J. Agardh

Smith, 1944; Papenfuss, 1944 (as *Zanardinula australis*)
Monterey, Calif.

Prionitis cornea (Okamura) Dawson

Smith, 1944 (as *Prionitis linearis*); Dawson, 1954 (as *Zauardinula cornea*); Papenfuss, 1944 (as *Zanardinula linearis*); Dawson, 1958, 1959*c*; Dawson, Neushul & Wildman, 1960
San Mateo Co., Calif., to Isla San Roque, Baja Calif.

Prionitis delicatula (Taylor) comb. nov.

Taylor, 1945: 210 (as *Prionitis filiformis* f. *delicatula*); Dawson, 1954 (as *Zanardinula delicatula*)
Central Pacific Baja Calif. south to Isla Magdalena

Prionitis filiformis Kylin

Doty, 1947 (as *Zanardinula filiformis*); Dawson, Neushul & Wildman, 1960*a*
Cape Arago, Oreg., to central Calif.; Punta Abreojos, Baja Calif.

Prionitis galapagensis Taylor

Taylor, 1945
Galapagos Arch.

Prionitis hancockii Taylor

Taylor, 1945
Galapagos Arch.

Prionitis lanceolata (Harvey) Harvey

Dawson, 1954 (as *Zanardinula lanceolata*); Scagel, 1957; Dawson, 1959*c*; Dawson, Neushul & Wildman, 1960
Southern British Columbia to Isla Cedros, Baja Calif.

Prionitis lyallii Harvey

Scagel, 1957; Dawson, 1954 (as *Zarnardinula lyallii* var. ?)
Southern British Columbia to Carmel Bay, Calif.; vicinity of Guaymas, Sonora ?

Prionitis mexicana Dawson

Dawson, 1954 (as *Zanardinula mexicana*)
Southern Baja Calif.

Prionitis vizcainensis (Dawson) Dawson, Neushul & Wildman

Dawson, 1954 (as *Zanardinula vizcainensis*); Dawson, Neushul & Wildman, 1960*a*
Bahía Vizcaino, Baja Calif.

Lobocolax deformans Howe

Doty, 1947; Dawson, 1954
Oreg. to central Baja Calif.

FAM. KALLYMENIACEAE

Kallymenia latiloba Taylor

Taylor, 1945
Galapagos Arch.

Kallymenia multiloba Taylor

Taylor, 1945
Galapagos Arch.

Kallymenia oblongifructa Setchell

Scagel, 1957
Sitka; Seldovia, Alaska, to Puget Sound, Wash.

Kallymenia ornata (Postels & Ruprecht) J. Agardh

Scagel, 1957
Yakutat Bay, Alaska, to Vancouver I., British Columbia

Kallymenia pacifica Kylin

Kylin, 1956 (as *Callymenia*); Dawson, Neushul & Wildman, 1960*a*
La Jolla, Calif.; Punta Eugenio, Baja Calif.

Kallymenia (?) *pertusa* Setchell & Gardner

Dawson, 1954 (as *Callymenia*)
Isla San Pedro Mártir, Gulf of Calif.

Kallymenia reniformis (Turner) J. Agardh f. *reniformis*

Scagel, 1957
Southern British Columbia

Kallymenia reniformis f. *cuneata* J. Agardh

Setchell & Gardner, 1903
Unalaska; Morzhovoi Bay, Alaska

Kallymenia setchellii Taylor

Taylor, 1945
Galapagos Arch.

Pugetia fragilissima Kylin

Scagel, 1957
Southern British Columbia to Monterey, Calif.

Callophyllis acrocarpa Setchell

Dawson, 1954*a*
Santa Cruz to Santa Barbara, Calif.

Callophyllis crassifolia Setchell & Swezy

Dawson, 1954*a*
San Mateo Co. to Carmel, Calif.

Callophyllis crenulata Setchell

Scagel, 1957
Northern British Columbia to Pacific Grove, Calif.

Callophyllis dissecta Setchell & Swezy

Dawson, 1954
San Pedro, Calif., to Punta San Quintín, Baja Calif.

Callophyllis edentata Kylin

Scagel, 1957
Hope I., British Columbia, to Oreg.

Callophyllis filicina Setchell & Swezy

Dawson, 1954*a*
Southern Calif.; Islas San Benito, Baja Calif.

Callophyllis firma (Kylin) Norris

Scagel, 1957
Northern British Columbia to Monterey, Calif.

Callophyllis flabellulata Harvey

Scagel, 1957
Northern British Columbia to Coos Bay, Oreg.

Callophyllis gardneri Setchell

Dawson, 1954*a*
Santa Rosa I., Calif., to Bahía Vizcaino, Baja Calif.

Callophyllis heanophylla Setchell

Scagel, 1957
Southern British Columbia to Coos Bay, Oreg.

Callophyllis (?) *ligulata* Taylor

Taylor, 1945
Isla Gorgona, Colombia; Galapagos Arch.

Callophyllis marginifructa Setchell & Swezy

Scagel, 1957; Dawson, 1954; Dawson, Neushul & Wildman, 1960, 1960*a*
Northern Wash. to Sacramento Reef, Baja Calif.

Callophyllis megalocarpa Setchell & Swezy

Dawson, 1954; Scagel, 1957
Northern Wash. to Isla Magdalena, Baja Calif.

Callophyllis obtusifolia J. Agardh

Dawson, 1954, 1959*c*
Santa Cruz, Calif., to Punta Santa Rosalía, Baja Calif.

Callophyllis odonthalioides Setchell

Dawson, 1954*a*
Santa Cruz to San Diego, Calif.

Callophyllis oregona Doty

Doty, 1947
North Bay and Brookings, Oreg.

Callophyllis phyllohaptera Dawson

Dawson, 1954
Punta Descanso to Isla Magdalena, Baja Calif.

Callophyllis pinnata Setchell & Swezy

Dawson, 1954*a*
Oreg. to Punta Baja, Baja Calif.

Callophyllis plumosa Setchell & Swezy

Dawson, 1954*a*, 1959*c*
San Pedro to La Jolla, Calif.

Callophyllis stenophylla Setchell

Dawson, 1949, 1954*a*
Bolinas; Santa Cruz I., Calif.

Callophyllis thompsonii Setchell

Scagel, 1957
Northern Wash.

Callophyllis violacea J. Agardh var. *violacea*

Doty, 1947; Dawson. 1954*a*, 1959*c*; Dawson, Neushul & Wildman, 1960, 1960*a*
Oreg.; Santa Barbara, Calif., to Isla Asunción, Baja Calif.

Callophyllis violacea var. *epiphytica* Dawson

Dawson, 1954, 1957
Central Baja Calif.; Rocas Alijos

Callocolax fungiformis Kylin

Scagel, 1957
Northern Wash.

Callocolax globulosis Dawson

Scagel, 1957
Northern Wash.; San Diego, Calif.

Erythrophyllum delesserioides J. Agardh

Scagel, 1957
Hope I., British Columbia, to San Luis Obispo Co., Calif.

Erythrophyllum gmelini (Grunow) Yendo

Okamura, 1933; Setchell & Gardner, 1903 (as *Callymenia gmelini*)
Atka to Agattu I., Aleutian Islands, Alaska

Erythrophyllum splendens Doty

Doty, 1947
Cape Arago, Oreg.

Euthora cristata (Linnaeus) J. Agardh

Setchell & Gardner, 1903
Shumagin I. to Cook Inlet, Alaska

Euthora fruticulosa (Ruprecht) J. Agardh

Okamura, 1933; Scagel, 1957
Bering Sea to northern Wash.

FAM. CHOREOCOLACEAE

Choreocolax polysiphoniae Reinsch

Dawson, 1954; Scagel, 1957
Sitka, Alaska, to Cabo Colnett, Baja Calif.

ORDER **GIGARTINALES**

FAM. CRUORIACEAE

Cruoria pacifica Kjellman

Hollenberg, 1948
Southern Calif.

Cruoria profunda Dawson

Dawson, 1961
Cortez Bank, off U.S.–Mexico boundary

Haematocelis rubens J. Agardh

Dawson, 1954, 1961
La Jolla, Calif., to Isla Magdalena, Baja Calif.

Cruoriopsis mexicana Dawson

Dawson, 1954, 1957*b*, 1960*a*, 1961
Islas Coronados, Baja Calif.; San Felipe, Gulf of Calif.; Golfo Dulce, Costa Rica

Petrocelis anastomosans Dawson

Dawson, 1961
Salina Cruz, Oaxaca

Petrocelis ascendens Dawson

Dawson, 1961
Bahía Rosario, Baja Calif.

Petrocelis franciscana Setchell & Gardner

Dawson, 1954, 1959*c*; Scagel, 1957; Dawson, 1961
Northern Wash. to Los Angeles Co., Calif.; Cabo Colnett, Baja Calif.

Petrocelis haematis Hollenberg

Hollenberg, 1943
Southern Calif.

Petrocelis middendorffii (Ruprecht) Kjellman

Scagel, 1957
Bering Sea to Whidbey Is., Wash.

FAM. NEMASTOMACEAE

Schizymenia epiphytica (Setchell & Lawson) Smith & Hollenberg

Smith, 1944; Papenfuss, 1944*a*
Monterey Peninsula, Calif.

Schizymenia pacifica (Kylin) Kylin

Scagel, 1957; Dawson, 1954, 1959*c*, 1961
Unga I., Alaska, to Isla Magdalena, Baja Calif.

Predaea masonii (Setchell & Gardner) J. De Toni

Dawson, 1954; Feldmann, 1942; Dawson, 1961
Isla Guadalupe, Baja Calif.; Isla Clarión, Revillagigedo Arch.; southern Gulf of Calif.

Predaea subpeltata Dawson

Dawson, 1961
Puerto Guatulco, Oaxaca

Platoma fanii Dawson

Dawson, 1961
Isla San Esteban, Gulf of Calif.

FAM. SEBDENIACEAE

Sebdenia rubra Taylor

Taylor, 1945
Galapagos Arch.

FAM. SOLIERIACEAE

Turnerella mertensiana (Postels & Ruprecht) Schmitz

Scagel, 1957
Shumagin I., Alaska, to northern Wash.

Eucheuma uncinatum Setchell & Gardner

Dawson, 1961
Isla Ángel de la Guarda, Gulf of Calif., to Mazatlán, Sinaloa

Agardhiella tenera (J. Agardh) Schmitz

Dawson, 1959*c* (as *A. coulteri*), 1961
Queen Charlotte Str., British Columbia, to Revillagigedo Arch.; Northern Gulf of Calif.; Galapagos Arch.

Gardneriella tuberifera Kylin

Hollenberg, 1948; Dawson, 1961
Monterey Peninsula, Calif., to Punta Baja, Baja Calif.

Opuntiella californica (Farlow) Kylin

Scagel, 1957
Unga I., Alaska, to San Diego, Calif.

Reticulobotrys catalinae Dawson

Dawson, 1961
Santa Catalina I., Calif.; Isla Guadalupe, Baja Calif.

Sarcodiotheca dichotoma (Howe) Dawson

Dawson, 1961
Puerto Refugio to La Paz, Gulf of Calif.

Sarcodiotheca divaricata Taylor

Taylor, 1945
Galapagos Arch.

Sarcodiotheca furcata (Setchell & Gardner) Kylin

Scagel, 1957; Dawson, 1961
Southern British Columbia to Islas Tres Marías Mexico; Puerto Culebra, Costa Rica; Galapagos Arch.

Sarcodiotheca linearis Setchell & Gardner

Dawson, 1961
Isla Magdalena to San Lucas, Baja Calif.

Sarcodiotheca taylorii Dawson

Dawson, 1961
Punta Frailes, Baja Calif.; Islas Tres Marías

Sarcodiotheca tenuis Taylor

Taylor, 1945; Dawson, 1961 (as probably equal to *S. divaricata*)
Galapagos Arch.

FAM. RHABDONIACEAE

Catenella repens (Lightfoot) Batters

Taylor, 1945
Galapagos Arch.; Esmeraldas, Ecuador

Catenella impudica (Montagne) J. Agardh

Taylor, 1945
Bahía Buenaventura, Colombia

FAM. RHODOPHYLLIDACEAE

Rhodophyllis dichotoma f. *setacea* Kjellman

Setchell & Gardner, 1903
Unalaska, Alaska

FAM. HYPNEACEAE

Hypneocolax stellaris f. *orientalis* Weber van Bosse

Dawson, 1961
Bahía Magdalena, Baja Calif.

Hypnea boergesenii Tanaka

Dawson, 1960*a*
Isla Brincanco, Panamá

Hypnea cervicornis J. Agardh

Taylor, 1945; Dawson, 1957, 1959, 1961
Isla Guadalupe, Scammon Lagoon, Bahía Santa María, Baja Calif.; San Felipe to Bahía San Lucas, Gulf of Calif.; Guayas, Ecuador; Galapagos Arch.

Hypnea johnstonii Setchell & Gardner

Dawson, 1958, 1961
Newport Harbor, Calif.; southern Baja Calif.; Gulf of Calif.; Isla San Benedicto; Revillagigedo Arch.; to San Blas, Nayarit

Hypnea marchantae Setchell & Gardner

Taylor, 1945
Isla Gorgona, Colombia; La Libertad, Ecuador

Hypnea pannosa J. Agardh

Dawson, 1954*c*, 1957*b*, 1961
Isla Pond, Gulf of Calif., to Islas Secas, Panamá; Galapagos Arch.

Hypnea spicifera (Suhr) Harvey ?

Dawson, 1961
Mazatlán, Sinaloa

Hypnea spinella (C. Agardh) Kützing

Dawson, 1959*b*, 1961
Guaymas, Sonora, to Bahía Petatlán, Guerrero; Clipperton I.

Hypnea valentiae (Turner) Montagne

Dawson, 1961
Santa Barbara, Calif., to Guayas, Ecuador

Hypnea variabilis Okamura

Dawson, 1961
Catalina I.; La Jolla, Calif., to Isla San Roque, Baja Calif.

FAM. PLOCAMIACEAE

Plocamium coccineum (Hudson) Lyngbye var. *coccineum*

Farlow, 1902
Galapagos Arch.

Plocamium coccineum var. *pacificum* (Kylin) Dawson

Dawson, 1957, 1959*c*; Scagel, 1957; Dawson, Neushul & Wildman, 1960, 1960*a* (all as *P. pacificum*); Dawson, 1961
Southern British Columbia to Rocas Alijos and Revillagigedo Arch.

Plocamium oreganum Doty

Scagel, 1957
Southern British Columbia to Sonoma Co., Calif.

Plocamium tenue Kylin

Scagel, 1957; Doty, 1947
Sitka, Alaska, to South Bay, Oreg.

Plocamium violaceum Farlow

Scagel, 1957; Dawson. 1959*c*, 1961
Southern British Columbia to Islas San Benito, Baja Calif.

Plocamiocolax pulvinata Setchell

Scagel, 1957; Dawson, 1961
Northern Wash. to Cabo Colnett, Baja Calif.; Isla Guadalupe

FAM. SPHAEROCOCCACEAE

Caulacanthus indicus Weber van Bosse

Dawson, 1957*b*
Golfo Dulce, Costa Rica ?

Caulacanthus ustulatus Kützing

Dawson, 1961
Isla Cedros to Isla Margarita, Baja Calif.; Isla Turner, Gulf of Calif.

Taylorophycus laxa (Taylor) Dawson

Dawson, 1961
Isla Magdalena, Baja Calif.

FAM. GRACILARIACEAE

Gelidiopsis tenuis Setchell & Gardner

Dawson, 1954, 1957*b*, 1959, 1961
Guaymas, Sonora, to Costa Rica; Revillagigedo Arch.

Gelidiopsis variabilis (Greville) Schmitz

Dawson, 1954, 1959, 1960*a*, 1961
Guaymas, Sonora, to Bahía Santiago, Colima

Gracilaria ascidiicola Dawson

Dawson, 1961
Puerto Escondido, Gulf of Calif.

Gracilaria brevis Taylor

Taylor, 1945
Guayas, Ecuador

Gracilaria cerrosiana Taylor

Dawson, 1961
Isla Cedros to Punta Abreojos, Baja Calif.

Gracilaria crispata Setchell & Gardner

Dawson, 1957*b*, 1961
Isla Tiburón, Sonora, to Costa Rica; Revillagigedo Arch.

Gracilaria ecuadoreanas (Taylor) Dawson

Dawson, 1949*b*
Galapagos Arch.

Gracilaria (?) *linearis* Kylin

Smith, 1944; Dawson, 1949*b* (as not of the genus *Gracilaria*)
Monterey Peninsula; Point Sur, Calif.

Gracilaria marcialana Dawson

Dawson, 1961
Bahía Agua Verde; Isla Espíritu Santo, Gulf of Calif.

Gracilaria pachydermatica Setchell & Gardner

Dawson, 1961
Isla Cedros to Isla Magdalena, Baja Calif.; throughout the Gulf of Calif.

Gracilaria ramisecunda Dawson

Dawson, 1961
Southern Gulf of Calif.

Gracilaria rubrimembra Dawson

Dawson, 1961
Vicinity of Guaymas, Sonora

Gracilaria rugulosa Montagne ?

Farlow, 1902
Galapagos Arch.

Gracilaria skottsbergii Taylor

Dawson, 1949*b*
Galapagos Arch.

Gracilaria spinigera Dawson

Dawson, 1961
Guaymas to Puerto Escondido, Gulf of Calif.; Isla Margarita, Baja Calif.

Gracilaria subsecundata Setchell & Gardner

Dawson, 1961
Throughout the Gulf of Calif. to Bahía Topolobampo, Sinaloa

Gracilaria symmetrica Dawson

Dawson, 1961
Bahía Chamela, Jalisco; Bahía Chacahua, Oaxaca; Bahía Santa Elena, Costa Rica

Gracilaria tepocensis (Dawson) Dawson

Dawson, 1961
Northern Gulf of Calif.; Costa Rica

Gracilaria textorii (Suringar) J. Agardh var. *textorii*

Dawson, 1961
Vicinity of Punta Eugenio; Punta Pequeña, Baja Calif.; Gulf of Calif.; Galapagos Arch.

Gracilaria textorii var. *cunninghamii* (Farlow) Dawson

Dawson, 1961; Dawson, Neushul, & Wildman, 1960 (as *G. cunninghamii*)
Santa Barbara, Calif., to Isla Magdalena, Baja Calif.

Gracilaria turgida Dawson

Dawson, 1961
Newport Harbor, Calif.; Bahía Magdalena, Baja Calif.

Gracilaria veleroae Dawson

Dawson, 1961
San Diego Co., Calif; northern Gulf of Calif. to Acapulco, Guerrero; Revillagigedo Arch.

Gracilaria verrucosa (Hudson) Papenfuss

Taylor, 1945 (as *G. confervoides* in part); Scagel, 1957; Dawson, 1961
Southern British Columbia to central Gulf of Calif.; Guayas, Ecuador ?

Gracilariopsis andersonii (Grunow) Dawson

Dawson, 1961; Kylin, 1941 (as *Gracilaria andersonii*)
Santa Barbara Co., Calif., to Punta María, Baja Calif.

Gracilariopsis claviformis Dawson

Dawson, 1961*a*
Near Santa Cruz I., Calif.

Gracilariopsis costaricensis Dawson

Dawson, 1957*b*, 1961
Bahía Tenacatita, Jalisco; Costa Rica

Gracilariopsis megaspora Dawson

Dawson, 1961
Bahía San Carlos, Sonora

Gracilariopsis panamensis (Taylor) Dawson

Dawson, 1949*b*
Puerto Culebra, Costa Rica; Isla Taboga, Panama; Galapagos Arch.

Gracilariopsis rhodotricha Dawson

Dawson, 1961
Revillagigedo Arch.

Gracilariopsis robusta (Setchell) Dawson

Dawson, 1949*b*
Monterey Peninsula, Calif.

Gracilariopsis sjoestedtii (Kylin) Dawson

Scagel, 1957; Dawson & Beaudette, 1960; Dawson, 1961
Vancouver I., British Columbia, to Bahía Salinas, Costa Rica

Gracilariophila gardneri Setchell

Dawson, 1945*c*, 1961
Santa Monica to La Jolla, Calif.; Bahía Bocochibampo, Sonora

Gracilariophila oryzoides Setchell & Wilson

Doty, 1947; Dawson, 1961
Coos Bay, Oreg., to Bahía Rosario, Baja Calif.

FAM. DICRANEMACEAE

Dicranema rosaliae Setchell & Gardner

Dawson, 1961
Throughout the Gulf of Calif. to Puerto Parker, Costa Rica

FAM. PHYLLOPHORACEAE

Phyllophora californica (J. Agardh) Kylin

Dawson, 1959*c*, 1961
San Francisco; Santa Barbara, Calif., to Punta San Hipólito, Baja Calif.

Phyllophora clevelandii Farlow

Dawson, 1961
Bolinas, Calif., to Socorro, Baja Calif.

Phyllophora submaritimus Dawson

Dawson, 1961
Cortes Bank, Calif.; Bahía Tortuga, Baja Calif.

Petroglossum pacificum Hollenberg

Hollenberg, 1943, 1945; Doty, 1947; Kylin, 1956 (as *Phyllophora pacificum*)
Coos Bay, Oreg., to La Jolla, Calif.

Petroglossum parvum Hollenberg

Dawson, 1959*c*, 1961
Laguna Beach, Calif., to Isla Cedros, Baja Calif.

Ahnfeltia concinna J. Agardh

Dawson 1954*c*, 1961; Scagel, 1957
Southern British Columbia to Oaxaca, Mexico; Isla San Benedicto, Revillagigedo Arch.

Ahnfeltia durvillaei (Bory) J. Agardh var. *durvillaei*

Taylor, 1945
Galapagos Arch.

Ahnfeltia durvillaei var. *implicata* (Kützing) Howe

Taylor, 1945
Galapagos Arch.

Ahnfeltia plicata (Hudson) Fries

Okamura, 1933; Scagel, 1957; Dawson, 1959*c*, 1961
Bering Sea to Punta Baja, Baja Calif.

Ahnfeltia svensonii Taylor

Dawson, 1961
Southern Gulf of Calif.; Galapagos Arch.

Gymnogongrus ? carnosus Setchell & Gardner

Dawson, 1961
Isla San Pedro Mártir, Gulf of Calif.

Gymnogongrus crustiforme Dawson

Dawson, 1961
Salina Cruz, Oaxaca

Gymnogongrus griffithsiae var. *galapagensis* Piccone & Grunow

Taylor, 1945
Galapagos Arch.

Gymnogongrus guadalupensis Dawson

Dawson, 1961
Isla Guadalupe; near Cabo San Lucas, Baja Calif.

Gymnogongrus johnstonii (Setchell & Gardner) Dawson

Dawson, 1961
Gulf of Calif. to Salina Cruz, Oaxaca; Bahía Salinas, Costa Rica; Revillagigedo Arch.

Gymnogongrus leptophyllus J. Agardh

Doty, 1947; Dawson, 1959*c*, 1961; Dawson, Neushul & Wildman, 1960
Oreg. to Punta Baja, Baja Calif.

Gymnogongrus linearis (Turner) J. Agardh

Doty, 1947
Cape Perpetua, Oreg., to San Luis Obispo Co., Calif.

Gymnogongrus martinensis Setchell & Gardner

Dawson, 1961
Isla San Martin to Isla Magdalena, Baja Calif.

Gymnogongrus melanothrix Grunow

Taylor, 1945
Galapagos Arch.

Gymnogongrus norvegicus (Gunner) J. Agardh

Scagel, 1957
Southern British Columbia to northern Wash.

Gymnogongrus platyphyllus Gardner

Scagel, 1957; Dawson, 1959*c*, 1961
Southern British Columbia to Punta Santa Rosalía, Baja Calif.

Gymnogongrus serenei Dawson

Dawson, 1961
Cabo San Lucas, Baja Calif.; Isla San Benedicto, Revillagigedo Arch.

Gymnogongrus smithii Taylor

Taylor, 1945
Galapagos Arch.

Gymnogongrus vermicularis J. Agardh

Taylor, 1945
Galapagos Arch.

Stenogramme interrupta (C. Agardh) Montagne

Dawson, 1959*c*, 1961; Scagel, 1957 (as *S. californica*); Kylin, 1956 (as *S. californica*); Dawson, Neushul & Wildman, 1960
Southern British Columbia to Cabo San Lucas, Baja Calif.; Revillagigedo Arch,; Galapagos Arch.

FAM. GIGARTINACEAE

Chondrus (?) *albemarlensis* Taylor

Taylor, 1945
Galapagos Arch.

Chondrus canaliculatus Greville

Farlow, 1902
Galapagos Arch.

Chondrus crispus (Linnaeus) Lyngbye

Setchell & Gardner, 1903
Bering Sea to Unalaska, Alaska

Chondrus (?) *hancockii* Taylor

Taylor, 1945
Galapagos Arch.

Gigartina agardhii Setchell & Gardner

Smith, 1944
Fort Ross to La Jolla ?, Calif.

Gigartina armata J. Agardh var. *armata*

Dawson, 1951*a*, 1961
Southern Calif. to Isla San Martín, Baja Calif. ?

Gigartina armata var. *echinata* (Gardner) Dawson

Dawson, 1961
Santa Catalina I.; La Jolla, Calif.; Isla Guadalupe, Baja Calif.

Gigartina asperifolia J. Agardh

Setchell & Gardner, 1933; Dawson, 1958, 1959*c*, 1961
Santa Barbara, Calif., to Punta Santa Rosalia, Baja Calif.

Gigartina californica J. Agardh

Smith, 1944; Sanborn & Doty, 1946; Doty, 1947; Dawson, 1959*c*, 1961
Coos Bay, Oreg., to near Punta María, Baja Calif.

Gigartina canaliculata Harvey

Doty, 1947; Dawson, 1959*c*, 1961; Dawson, Neushul & Wildman, 1960
Coos Bay, Oreg., to Isla Magdalena, Baja Calif.

Gigartina chauvinii (Bory) Montagne

Taylor, 1945
Galapagos Arch.

Gigartina corymbifera (Kützing) J. Agardh

Scagel, 1957 (in part as *G. binghamii*); Dawson, 1961
Northern Wash. to San Quintin, Baja Calif.

Gigartina dichotoma Gardner

Setchell & Gardner, 1933
Duxbury Reef to Point Sur, Calif.

Gigartina exasperata Harvey & Bailey

Scagel, 1957
Southern British Columbia to northern Calif.

Gigartina harveyana (Kützing) Setchell & Gardner

Doty, 1947; Dawson, 1959*c*, 1961
Oreg. to near Punta María, Baja Calif.

Gigartina intermedia Suringar

Dawson, 1961
Isla Tortuga, Gulf of Calif.; Mazatlan, Sinaloa

Gigartina jardinii J. Agardh

Setchell & Gardner, 1933
Monterey; Santa Barbara, Calif.

Gigartina johnstonii Dawson

Dawson, 1961
Northern Gulf of Calif. south to Guaymas

Gigartina latissima (Harvey) Eaton

Scagel, 1957
Table I., British Columbia, to northern Wash.

Gigartina leptorhynchos J. Agardh f. *leptorhynchos*

Dawson, 1959*c*, 1961
Santa Cruz, Calif., to Isla Cedros, Baja Calif.

Gigartina leptorhynchos f. *latissima* Dawson

Dawson, 1949, 1961
Point Arguello, Calif.; Isla San Martín, Baja Calif.

Gigartina leptorhynchos f. *cylindrica* Dawson

Dawson, 1949, 1954, 1961
Southern Calif. and northern Baja Calif.

Gigartina lessonii J. Agardh

Farlow, 1902
Galapagos Arch.

Gigartina macdougalii Dawson

Dawson, 1961
Northern Gulf of Calif. south to Isla Tiburón

Gigartina mamillosa (Goodenough & Woodward) J. Agardh

Scagel, 1957
Southern British Columbia to Seal Rocks, Oreg.

Gigartina multidichotoma Dawson

Dawson, 1961
Santa Catalina I.; La Jolla, Calif.; Punta Descanso, Baja Calif.

Gigartina papillata (C. Agardh) J. Agardh f. *papillata*

Scagel, 1957 (in part as *G. cristata*); Dawson, 1959*c*, 1961; Hollenberg, 1948
Northern Wash. to Punta Baja, Baja Calif.

Gigartina papillata f. *cristata* Setchell

Scagel, 1957; Dawson, 1959*c* (both as *G. cristata*), Dawson, 1961
Northern Wash. to Bahía Rosario, Baja Calif.

Gigartina pectinata Dawson

Dawson, 1961
Northern Gulf of Calif.

Gigartina serrata Gardner

Setchell & Gardner, 1933; Dawson, 1959*c*, 1961
Balboa, Calif., to Isla Magdalena, Baja Calif.

Gigartina sitchensis Ruprecht

Scagel, 1957
Sitka, Alaska, to Whidbey I., Wash.

Gigartina spinosa (Kützing) Harvey

Coe, 1932; Smith, 1944; Dawson, 1959*c*, 1961
Monterey, Calif., to Punta Baja, Baja Calif.

Gigartina stellata (Stackhouse) Batters

Scagel, 1957
West Coast of Vancouver I., British Columbia

Gigartina tepida Hollenberg

Dawson, 1959, 1961
Balboa Harbor, Calif.; Bahía San Quintin, Baja Calif.; northern Gulf of Calif. south to Topolobampo, Sinaloa

Gigartina turneri Setchell & Gardner

Setchell & Gardner, 1933; Dawson, 1945*b*
Southern Calif.

Gigartina unalaschensis (Ruprecht) Ruprecht

Scagel, 1957
Bering Sea to northern Wash.

Gigartina volans (C. Agardh) J. Agardh

Doty, 1947; Dawson, 1959*c*, 1961; Dawson, Neushul & Wildman, 1960
Coos Bay, Oreg., to near Punta María, Baja Calif.

Rhodoglossum affine (Harvey) Kylin

Scagel, 1957; Dawson, 1959*c*, 1961
Southern British Columbia to Isla San Roque, Baja Calif.

Rhodoglossom americanum Kylin

Smith, 1944; Dawson, 1945*b*, 1958, 1959*c*, 1961
Bolinas, Calif., to near Punta María, Baja Calif.

Rhodoglossum cobinae Dawson

Dawson, 1961
Punta María to Isla Magdalena, Baja Calif.

Rhodoglossum coriaceum Dawson

Dawson, 1958, 1959*c*, 1961
Santa Cruz I.; Ventura, Calif., to near Punta María, Baja Calif.

Rhodoglossum diffusum Dawson

Dawson, 1961
Isla Ángel de la Guarda, Gulf of Calif.

Rhodoglossum digitatum Dawson

Dawson, 1961
Isla Partida; Isla Rasa, Gulf of Calif.

Rhodoglossum hancockii Dawson

Dawson, 1961
Northern Gulf of Calif.

Rhodoglossum latissimum J. Agardh

Scagel, 1957
Northern British Columbia to northern Wash.

Rhodoglossum linguiforme Dawson

Dawson, 1961
Arroyo Hondo, southern Calif., to Punta Cono (?), Baja Calif.

Rhodoglossum parvum Smith & Hollenberg

Smith, 1944; Hollenberg, 1948
Monterey; southern Calif.

Rhodoglossum roseum (Kylin) G. M. Smith

Smith, 1944; Dawson, 1959*c*, 1961
Monterey Peninsula, Calif.; Punta Descanso to Punta Baja, Baja Calif.

Iridaea agardhiana (Setchell & Gardner) Kylin

Smith, 1944; Sanborn & Doty, 1946; Doty, 1947 (all as *Iridophycus flaccidum*); Kylin, 1941; Dawson, 1959*c* (as *Iridaea flaccidum*)
Cape Arago, Oreg., to Government Point, Calif.

Iridaea californica J. Agardh

Kylin, 1941
Santa Barbara, Calif.

Iridaea cordata (Turner) Bory

Scagel, 1957
Banks I., British Columbia to Oreg.

Iridaea coriaceum (Setchell & Gardner) Scagel

Scagel, 1957
Northern Wash. to Carmel, Calif.

Iridaea fulgens (Setchell & Gardner) Papenfuss

Setchell & Gardner, 1937; Doty, 1947 (both as *Iridophycus fulgens*); Papenfuss, 1958
Cape Arago, Oreg.; Trinidad, Humbolt Co., Calif.

Iridaea furcata (Setchell & Gardner) Papenfuss

Papenfuss, 1958
Sitka, Alaska

Iridaea heterocarpa Postels & Ruprecht

Scagel, 1957; Dawson, 1959*c*
Northern British Columbia to Government Point, Calif.

Iridaea lineare (Setchell & Gardner) Kylin

Smith, 1944; Doty, 1947 (both as *Iridophycus lineare*); Kylin, 1941; Dawson, 1959*c*
Cape Mears, Oreg., to Ventura, Calif.

Iridaea oregana (Doty) Papenfuss

Papenfuss, 1958
Brookings, Oreg.

Iridaea parksii (Setchell & Gardner) Papenfuss

Papenfuss, 1958
Trinidad, Calif.

Iridaea parvula (Kjellman) Papenfuss

Okamura, 1933 (as *Iridaea laminarioides* var. *parvula*); Papenfuss, 1958
Aleutian Islands to Kodiak I., Alaska

Iridaea reediae (Setchell & Gardner) Papenfuss

Dawson, 1958, 1959*c*; Papenfuss, 1958
Bushnell's Beach, San Luis Obíspo Co., and Solromar, Ventura Co., Calif.

Iridophycus sanguineum Setchell & Gardner

Kylin, 1941; Dawson, 1945*c* (both as probably identical with *Iridaea californica*); Doty, 1947
Cape Arago, Oreg., to Pacific Grove, Calif.

Iridaea sinicola (Setchell & Gardner) Papenfuss

Papenfuss, 1958
San Francisco Bay, Calif.

Iridaea splendens (Setchell & Gardner) Papenfuss

Doty, 1947 (as *Iridophycus splendens*); Papenfuss, 1958; Dawson, 1958, 1959*c*
Cape Kiawandi, Oreg.; Monterey Peninsula and Government Point, Calif.

Iridaea whidbeyanum (Setchell & Gardner) Scagel

Scagel, 1957
Southern British Columbia to Oreg.

Besa papillaeformis Setchell

Smith, 1944
Lands End, San Francisco; Monterey, Calif.

ORDER **RHODYMENIALES**

FAM. RHODYMENIACEAE

Fauchea (?) *crispa* Taylor

Dawson, 1954
Isla María Magdalena, Nayarit

Fauchea fryeana Setchell

Scagel, 1957
Southern British Columbia to northern Wash.

Fauchea galapagensis Taylor f. *galapagensis*

Taylor, 1945
Galapagos Arch.

Fauchea galapagensis f. *pygmaea Taylor*

Taylor, 1945
Galapagos Arch.

Fauchea laciniata J. Agardh var. *laciniata*

Dawson, 1954; Scagel, 1957; Sparling, 1957; Dawson, Neushul & Wildman 1960, 1960a; Hollenberg, 1948 (as *F. media*)
Southern British Columbia to Isla Asunción, Baja Calif.

Fauchea laciniata f. *pygmaea* Setchell & Gardner

Kylin, 1941; Dawson, 1949*a* (both as *F. pygmaea*); Dawson, 1954; Dawson, Neushul & Wildman, 1960*a*; Sparling, 1957 (as *F. laciniata*)
Throughout the southern part of the range of the species

Fauchea mollis Howe

Dawson, 1954
La Paz, Baja Calif.

Fauchea rhizophylla Taylor

Taylor, 1945
Galapagos Arch.

Fauchea sefferi Howe

Dawson, 1954
La Paz, Baja Calif.

Faucheocolax attenuata Setchell

Scagel, 1957; Sparling, 1957
Northern Wash. to Monterey Peninsula, Calif.

Gloioderma conjuncta (Setchell & Gardner) Dawson

Dawson, 1954 (as *Estebania conjuncta*); Dawson, 1959
Northern Gulf of Calif. south to Isla Tortuga

Sciadophycus stellatus Dawson

Dawson, 1954; Dawson, Neushul & Wildman, 1960
Southern Calif. to southern Baja Calif.

Leptofauchea pacifica Dawson

Dawson, 1954
Isla Cedros, Baja Calif.

Fryella gardneri (Setchell) Kylin

Scagel, 1957
Southern British Columbia to Oreg.

Botryocladia beaudettei Dawson

Dawson, 1960*a*
Bahía Potrero Grande, Costa Rica

Botryocladia chiajeana (Meneghini) Kylin ?

Dawson, 1957 Dawson, Neushul & Wildman, 1960*a*
Near Punta Eugenio; Rocas Alijos, Baja Calif.

Botryocladia hancockii Dawson

Dawson, 1954
Bahía Agua Verde, Gulf of Calif.

Botryocladia neushulii Dawson

Dawson 1958; Dawson, Neushul & Wildman, 1960
Goleta, Calif., to Bahía San Quintín, Baja Calif.

Botryocladia pseudodichotoma (Farlow) Kylin var. *pseudodichotoma*

Scagel, 1957; Dawson, 1954; Dawson, Neushul & Wildman, 1960, 1960*a*
Vancouver I., British Columbia, to Isla María Magdalena, Nayarit; Isla Socorro, Revillagigedo Arch.; Galapagos Arch.

Botryocladia pseudodichotoma var. *datilensis* Dawson

Dawson, 1954
Isla Tiburón; near Guaymas, Gulf of Calif.

Botryocladia tenuissima Taylor

Taylor, 1945
Galapagos Arch.

Botryocladia uvarioides Dawson

Dawson, 1954, 1959
Southern Gulf of Calif.

Halosaccion glandiforme (Gmelin) Ruprecht

Scagel, 1957
Westernmost Aleutian Islands, Alaska, to Monterey Peninsula, Calif.

Halosaccion ramentaceum (Linnaeus) J. Agardh

Setchell & Gardner, 1903
Sannak I. to Cook Inlet, Alaska

Halosaccion tilesii Kjellman

Setchell & Gardner, 1903
Kukak Bay to Wrangel, Alaska

Drouetia coalescens (Farlow) G. De Toni

G. De Toni, 1938; Taylor, 1945 (as *Herpophyllon coalescens*); Dawson, 1949
Galapagos Arch.

Drouetia rotata Dawson

Dawson, 1949; Dawson, Neushul & Wildman, 1960 (partly as *D. peltata* by error), 1960*a*
Southern Calif. Channel Islands to Baja Calif.

Rhodymenia arborescens Dawson

Dawson, 1954; Dawson, Neushul & Wildman, 1960, 1960*a*
Southern Calif. to Isla Magdalena, Baja Calif.

Rhodymenia attenuata Dawson

Smith, 1944; Dawson, Neushul & Wildman, 1960, 1960*a*
Monterey, Calif., to Isla Asunción, Baja Calif.

Rhodymenia californica Kylin

Taylor, 1945; Dawson, 1954, 1949*a*, 1951*a*, 1959, 1959*c*; Scagel, 1957; Sparling, 1957; Dawson, Neushul & Wildman, 1960
Southern British Columbia to Isla Magdalena, Baja Calif.; Isla Carmén, Gulf of Calif.; Galapagos Arch.

Rhodymenia dawsonii Taylor

Dawson, 1954; Dawson, Neushul & Wildman, 1960*a*
Bahía Tortuga, Isla Magdalena, Baja Calif.

Rhodymenia decumbens Taylor

Taylor, 1945
Galapagos Arch.

Rhodymenia divaricata Dawson

Taylor, 1945; Dawson, 1954
Northern Gulf of Calif.; Galapagos Arch.

Rhodymenia flabellifolia Bory

Taylor, 1945; Dawson, 1941
Galapagos Arch.

Rhodymenia hancockii Dawson

Dawson, 1954, 1959
Isla Ángel de la Guarda; Bahía Agua Verde, Gulf of Calif.

Rhodymenia lobata Dawson

Smith, 1954; Dawson, 1954
Monterey, Calif.; near Isla Isabel, Nayarit

Rhodymenia lobulifera Dawson

Smith, 1944; Dawson, 1959*c*
Bolinas to San Pedro, Calif.

Rhodymenia pacifica Kylin

Scagel, 1957; Sparling, 1957; Dawson, 1959*c*; Dawson, Neushul & Wildman, 1960, 1960*a*
Northern British Columbia to Punta Cabras, Baja Calif.

Rhodymenia palmata (Linnaeus) Greville f. *palmata*

Okamura, 1933; Scagel, 1957
Aleutian Islands, Alaska, to northern Wash.

Rhodymenia palmata f. *mollis* Setchell & Gardner

Scagel, 1957
Agattu I., Alaska, to Pacific Grove, Calif.

Rhodymenia palmata f. *sarniensis* (Mertens) J. Agardh

Setchell & Gardner, 1903
Kodiak Is. to Orca, Alaska

Rhodymenia palmetta (Esper) Greville

Taylor, 1945
Galapagos Arch.

Rhodymenia palmettiformis Dawson

Dawson, 1945, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
La Jolla, Calif., to Punta Baja, Baja Calif.

Rhodymenia pertusa (Postels & Ruprecht) J. Agardh

Scagel, 1957; Sparling, 1957
Alaska to Coos Bay, Oreg.

Rhodymenia rhizoides Dawson

Dawson, 1941, 1945, 1959*c*
Lechuza Point to San Diego, Calif.

Rhodymenia rosea Dawson

Dawson, 1954
Isla Ángel de la Guarda, Gulf of Calif.

Rhodymenia stipitata Kylin

Scagel, 1957
British Columbia; Puget Sound, Wash.

Rhodymeniocolax botryoidea Setchell

Scagel, 1957; Sparling, 1957
Northern Wash. to San Diego, Calif.

FAM. LOMENTARIACEAE

Binghamia californica J. Agardh

Silva, 1952
Santa Barbara to Santa Monica, Calif.

Binghamia forkii (Dawson) Silva

Dawson, 1945; Hollenberg, 1948 (both as *Binghamiella*); Dawson, 1954, 1957 (as *Binghamiella* by error); Dawson, Neushul & Wildman, 1960, 1960*a*
Laguna Beach, Calif., to Isla Asunción; Rocas Alijos, Baja Calif.

Lomentaria baileyana (Harvey) Farlow

Dawson, 1954
Bahía Vizcaino, Baja Calif.; Revillagigedo Arch.; Puerto Culebra, Costa Rica

Lomentaria caseae Dawson

Dawson, 1946
Del Mar, Calif.

Lomentaria catenata Harvey

Dawson, 1954
Punta Santa Rosalía; Isla Magdalena, Baja Calif.; northern Gulf of Calif.

Lomentaria hakodatensis Yendo

Dawson, 1954, 1960*a*; Dawson, Neushul & Wildman, 1960*a*
Isla Guadalupe; Islas San Benito; Laguna de San Ignacio, Baja Calif.; northern Gulf of Calif. to Puerto Culebra, Costa Rica

Champia parvula (C. Agardh) Harvey

Taylor, 1945; Dawson, 1954, 1954*c*, 1957*b*; 1959
Revillagigedo Arch.; Gulf of Calif. to Golfo de Nicoya, Costa Rica; Esmeraldas, Ecuador

Gastroclonium coulteri (Harvey) Kylin

Scagel, 1957; Dawson, 1954, 1958*c*; Dawson, Neushul & Wildman, 1960
Nootka Sound, British Columbia, to Bahía Asunción, Baja Calif.

Coeloseira compressa Hollenberg

Dawson, 1954; Dawson, Neushul & Wildman, 1960*a*
Pacific Grove, Calif., to Isla Asunción, Baja Calif.

Coeloseira pacifica Dawson

Dawson, 1954
Northern Gulf of Calif. south to Guaymas

Coeloseira parva Hollenberg

Dawson, 1954
Redondo, Calif., to Punta Santa Rosalía, Baja Calif.

ORDER CERAMIALES

FAM. CERAMIACEAE

Crouania attenuata (Bonnemaison) J. Agardh

Dawson, 1954, 1957
Isla Guadalupe; Bahía Vizcaino; Rocas Alijos, Baja Calif.

Lejolisia colombiana Taylor

Taylor, 1945
Isla Gorgona, Colombia

Gymnothamnium elegans (Schousboe) J. Agardh

Hollenberg, 1948; Dawson, 1954; Taylor, 1945
Southern Calif.; Isla Clarión, Revillagigedo Arch.; Galapagos Arch.

Antithamnion alternans Gardner

Gardner, 1927*b*
Cook Inlet, Alaska

Antithamnion asymmetricum Gardner

Gardner, 1927*c*
Sitka, Alaska

Antithamniun baylesiae Gardner

Doty, 1947
South Slough, near Charleston, Oreg.; Monterey Peninsula, Calif.

Antithamnion breviramosus Dawson

Dawson, 1954, 1957, 1957*b*, 1959, 1960*a*
Santa Catalina I., Calif., to Isla del Rey, Panama; southern Gulf of Calif.

Antithamnion defectum Kylin

Scagel, 1957
Northern British Columbia to Monterey, Calif.

Antithamnion dendroideum Smith & Hollenberg

Smith, 1944
Monterey, Calif.

Antithamnion densiusculum Gardner

Scagel, 1957
Southern British Columbia to Pacific Grove, Calif.

Antithamnion dumontii Dawson

Dawson, 1960*a*
Isla del Caño, Costa Rica, to Isla Jicarón, Panama

Antithamnion floccosum (Müller) Kleen

Scagel, 1957
Southern British Columbia to northern Wash.

Antithamnion gardneri G. De Toni

G. De Toni, 1935; Doty, 1947 (as *A. tenuissimum*)
Coos Bay, Oreg.; La Jolla, Calif.

Antithamnion glanduliferum Kylin

Scagel, 1957; Dawson, 1954*d*; Dawson, Neushul & Wildman, 1960*a*
Southern British Columbia to Isla Asunción, Baja Calif.

Antithamnion kylinii Gardner

Scagel, 1957; Dawson, 1954
Victoria, British Columbia, to Punta San Hipólito, Baja Calif.

Antithamnion mcnabbii Dawson

Dawson, 1959
Bahía Agua Verde, Gulf of Calif.

Antithamnion nigricans Gardner

Scagel, 1957
Vancouver I., British Columbia

Antithamnion occidentale Kylin

Taylor, 1945; Scagel, 1957
Alaska to La Jolla, Calif.; Galapagos Arch.

Antithamnion pacificum (Harvey) Kylin

Dawson, 1954; Scagel, 1957
Yakutat Bay, Alaska, to La Jolla, Calif.; northern Gulf of Calif.

Antithamnion pulchellum Gardner

Gardner, 1927*c*
Santa Monica, Calif.

Antithamnion pygmaeum Gardner

Doty, 1947; Dawson, 1949; Dawson, Neushul & Wildman, 1960*a*
Oreg. to Punta Eugenio, Baja Calif.

Antithamnion secundatum Gardner

Gardner, 1927*c*
San Diego, Calif.

Antithamnion setaceum Gardner

Gardner, 1927*c*
San Diego, Calif.

Antithamnion simulans Gardner

Gardner, 1927*b*
Sitka, Alaska

Antithamnion sublittorale Setchell & Gardner

Dawson, 1954
San Jose del Cabo, Baja Calif.

Antithamnion subulatum (Harvey) J. Agardh

Scagel, 1957
Southern British Columbia to Monterey, Calif.

Antithamnion uncinatum Gardner

Scagel, 1957
Northern Wash. to Carmel, Calif.

Antithamnion veleroae Taylor

Taylor, 1945
Galapagos Arch.

Platythamnion heteromorphum (J. Agardh) J. Agardh

Doty, 1947
Oreg. to San Pedro, Calif.

Platythamnion pectinatum Kylin var. *pectinatum*

Dawson, 1954; Scagel, 1957
Hope I., British Columbia, to Cabo Colnett, Baja Calif.

Platythamnion pectinatum var. *laxum* Taylor

Dawson, 1954
Isla Clarión, Revillagigedo Arch.

Platythamnion reversum (Setchell & Gardner) Kylin var. *reversum*

Scagel 1957
Northern Wash. to Oreg.

Platythamnion reversum var. *laxum* Taylor

Taylor, 1945
Galapagos Arch.

Platythamnion tepocensis Dawson

Dawson, 1954
Bahía Tepoca, Gulf of Calif.

Platythamnion villosum Kylin

Dawson, 1954; Scagel, 1957; Dawson, Neushul & Wildman, 1960*a*
Sitka, Alaska, to Bahía Tortuga, Baja Calif.

Ceramium affine Setchell & Gardner var. *affine*

Taylor, 1945; Dawson, 1954
Isla Guadalupe, Baja Calif.; Isla Ángel de la Guarda, Gulf of Calif.; Guayas, Ecuador

Ceramium affine var. *peninsularis* Dawson

Dawson, 1954
Corona del Mar, Calif.; Scammon Lagoon, Baja Calif.; Punta Frailes, Gulf of Calif.

Ceramium avalonae Dawson

Dawson, 1954, 1960*a*
Santa Catalina I., Calif.; Isla Guadalupe, Baja Calif.; Puerto Culebra; Bahía Potrero Grande, Costa Rica

Ceramium californicum J. Agardh

Dawson, 1954, 1959*c*; Scagel, 1957
Southern British Columbia to Bahía Magdalena, Baja Calif.

Ceramium camouii Dawson

Dawson, 1954, 1957
Punta Banda; Bahía Vizcaino; Rocas Alijos, Baja Calif.; Gulf of Calif.

Ceramium caudatum Setchell & Gardner

Dawson, 1954, 1959
Balboa Harbor; Santa Catalina I., Calif.; Isla Guadalupe Baja Calif.; Gulf of Calif.

Ceramium clarionense Setchell & Gardner

Dawson, 1954, 1957
Balboa Harbor, Calif., to Isla Cedros; Rocas Alijos, Baja Calif.; Isla Jorge, Gulf of Calif. to Miramar, Nayarit; Revillagigedo Arch.

Ceramium codicola J. Agardh

Dawson, 1954; Scagel, 1957
Sitka, Alaska, to Bahía Tortuga, Baja Calif.

Ceramium eatonianum (Farlow) J. B. De Toni

Doty, 1947: Dawson, 1954, 1959*c*
Coos Bay, Oreg. to Isla Magdalena, Baja Calif.

Ceramium equisetoides Dawson

Dawson, 1954, 1957*b*
Balboa Harbor, Calif.; Bahía Tepoca, Sonora to Mazatlán, Sinaloa; Golfo de Nicoya, Costa Rica

Ceramium evermannii Setchell & Gardner

Dawson, 1954
Isla Guadalupe, Baja Calif.

Ceramium fimbriatum Setchell & Gardner

Dawson, 1954, 1959
Punta Banda to Cabeza Ballena, Baja Calif.; Isla Ángel de la Guarda, Gulf of Calif. to Acapulco, Guerrero

Ceramium gardneri Kylin

Doty, 1947; Dawson, 1950*d*
Coos Bay, Oreg., to Santa Cruz I. and Ventura, Calif.

Ceramium gracillimum var. *byssoideum* (Harvey) G. Mazoyer

Dawson, 1950*d*, 1954 (both as *C. masonii*), 1956, 1957*b*, 1959; Taylor, 1945 (as *C. byssoideum*)
Corona del Mar, Calif., to Cabeza Ballena, Baja Calif.; Gulf of Calif.; Costa Rica; Galapagos Arch.

Ceramium hamatispinum Dawson

Dawson, 1954
Miramar, Nayarit

Ceramium hoodii Taylor

Taylor, 1945
Galapagos Arch.

Ceramium horridum Setchell & Gardner

Dawson, 1954
Gulf of Calif.

Ceramium howellii Setchell & Gardner

Setchell & Gardner, 1937; Dawson, 1957
Galapagos Arch.

Ceramium marshallense Dawson

Dawson, 1957*b*
Golfo de Nicoya, Costa Rica

Ceramium mazatlanense Dawson

Dawson, 1954, 1954*c*, 1957*b*, 1959*b*
Kino, Sonora, to Salina Cruz, Oaxaca; Golfo Dulce, Costa Rica; Isla San Benedicto, Revillagigedo Arch.; Clipperton I. ?

Ceramium nakamurai Dawson

Dawson, 1957*b*
Golfo de Nicoya, Costa Rica

Ceramium obesum Dawson

Dawson, 1954
Bahía Agua Dulce, Isla Tiburón, Sonora

Ceramium ornatum Setchell & Gardner

Dawson, 1954
Isla Guadalupe, Baja Calif.

Ceramium pacificum (Collins) Kylin

Scagel, 1957; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Northern British Columbia to Punta María, Baja Calif.

Ceramium paniculatum Okamura

Dawson, 1954, 1959
Guaymas, Sonora, to Mazatlán, Sinaloa

Ceramium personatum Setchell & Gardner

Taylor, 1945; Dawson, 1954
Isla Guadalupe; vicinity of Punta Santa Rosalía, Baja Calif.; Puerto Parker, Costa Rica ?

Ceramium procumbens Setchell & Gardner

Hollenberg, 1948; Dawson, 1954, 1959, 1960*a*
Southern Calif. to Punta Santa Rosalía, Baja Calif.; Gulf of Calif.; Bahía Ballena, Costa Rica

Ceramium recticorticum Dawson

Dawson, 1954
Guaymas, Sonora; Mazatlán, Sinaloa

Ceramium rubrum (Hudson) C. Agardh

Scagel, 1957
Bering Sea to northern Wash.

Ceramium serpens Setchell & Gardner

Dawson, 1949*a*, 1954, 1957
Gulf of Calif.; Clipperton I. ?; Galapagos Arch. ?

Ceramium sinicola Setchell & Gardner var. *sinicola*

Dawson, 1954, 1957, 1959
Southern Calif. and Pacific Baja Calif.; Rocas Alijos; Isla San Benedicto, Revillagigedo Arch.; northern Gulf of Calif.

Ceramium sinicola var. *interrupta* (Setchell & Gardner) Dawson

Hollenberg, 1948; Dawson, 1954, 1959
Same range as the species

Ceramium sinicola var. *johnstonii* (Setchell & Gardner) Dawson

Dawson, 1954
Same range as the species

Ceramium strictum Harvey

Dawson, 1950*c* (as probably referable to *C. gardneri*); Scagel, 1957
Southern British Columbia

Ceramium taylorii Dawson

Taylor, 1945 (as *C. fastigiatum*); Dawson, 1954, 1954*c*, 1957*b*, 1959
Laguna Beach, Calif., to Bahía Magdalena, Baja Calif.; Gulf of Calif. to Acapulco, Guerrero; Isla San Benedicto, Revillagigedo Arch.; Golfo de Nicoya, Costa Rica; Galapagos Arch. ?

Ceramium templetonii Setchell & Gardner

Setchell & Gardner, 1937; Dawson, 1957
Galapagos Arch.

Ceramium vagabunde Dawson

Dawson, 1954*c* (as *Ceramium* sp.), 1957*a*, 1957*b*
Isla San Benedicto, Revillagigedo Arch.; Golfo Dulce, Costa Rica

Ceramium viscainoense Dawson

Dawson, 1954
Punta Santa Rosalía, Baja Calif.

Ceramium zacae Setchell & Gardner

Dawson, 1954, 1957, 1959; Dawson, Neushul & Wildman, 1960*a*
Southern Calif. to Rocas Alijos; Punta Abreojos, Baja Calif.; Bahía Agua Verde, Gulf of Calif.

Centroceras bellum Setchell & Gardner

Dawson, 1954
Guaymas, Sonora

Centroceras clavulatum (C. Agardh) Montagne var. *clavulatum*

Dawson, 1954, 1954*c*, 1957, 1957*b*, 1959, 1959*c*; Taylor, 1945

Santa Cruz, Calif., to Panamá; Galapagos Arch.

Centroceras clavulatum var. *inerme* (Kützing) Piccone

Dawson, 1957

Galapagos Arch.

Centroceras minutum Yamada

Dawson, 1960*a*

Isla Brincanco, Panamá

Microcladia borealis Ruprecht

Okamura, 1933; Scagel, 1957

Aleutian Islands, Alaska, to San Simeon, Calif.

Microcladia californica Farlow

Smith, 1944

San Francisco to San Diego, Calif.

Microcladia coulteri Harvey

Dawson, 1954, 1959*c*, Scagel, 1957; Dawson, Neushul & Wildman, 1960

Vancouver I., British Columbia, to Punta Santa Rosalía, Baja Calif.

Neoptilota asplenioides (Esper) Kylin

Kylin, 1956; Scagel, 1957 (as *Ptilota asplenioides*)

Yakutat Bay, Alaska, to Puget Sound, Wash.

Neoptilota californica (Ruprecht) Kylin

Kylin, 1956; Scagel, 1957 (as *Ptilota californica*)

Northern British Columbia to San Diego, Calif.

Neoptilota densa (C. Agardh) Kylin

Kylin, 1956; Dawson, 1954 (as *Plumaria densa*); Smith, 1944; Dawson, 1945*b* both as *Ptilota densa*)

Tomales Bay, Calif., to Punta Baja, Baja Calif.

Neoptilota hypnoides (Harvey) Kylin

Kylin, 1956; Scagel, 1957 (as *Ptilota hypnoides*)

Sitka, Alaska, to San Luis Obispo Co., Calif.

Ptilota filicina (Farlow) J. Agardh

Kylin, 1956; Scagel, 1957; Dawson, 1954 (as *Plumaria filicina*); Dawson, 1949*a*, 1959*c* (both as *Ptilota filicina*)

Bering Sea to Cabo Colnett, Baja Calif.

Ptilota pectinata (Gunner) Kjellman

Kylin, 1956; Scagel, 1957

Bering Sea to Puget Sound, Wash.

Ptilota tenuis Kylin

Kylin, 1956; Scagel, 1957

Northern British Columbia to northern Wash.

Spyridia filamentosa (Wulfen) Harvey

Kylin, 1941; Taylor, 1945; Dawson, 1954, 1957*b*

Southern Calif. to Panamá

Wrangelia argus (Montagne) Montagne

Dawson, 1960*a*

Punta Naranja, Panamá

Callithamnion acutum Kylin

Scagel, 1957

Northern Wash.

Callithamnion arborescens Gardner

Gardner, 1927*b*

Sitka, Alaska

Callithamnion biseriatum Kylin

Scagel, 1957

Northern British Columbia to Monterey, Calif.

Callithamnion bisporum Gardner

Scagel, 1957

Northern Wash.

Callithamnion breviramosum Gardner

Gardner, 1927*c*

La Jolla, Calif.

Callithamnion byssoides Arnott

Dawson, 1954, 1960*a*

Isla Guadalupe, Baja Calif.

Callithamnion californicum Gardner

Smith, 1944
Monterey Peninsula, Calif.

Callithamnion ecuadoreanum Taylor

Taylor, 1945
Galapagos Arch.

Callithamnion endovaginum Setchell & Gardner

Kylin, 1941; Dawson, 1944, 1954
La Jolla, Calif.; Guaymas, Sonora

Callithamnion epiphyticum Taylor

Taylor, 1945
Galapagos Arch.

Callithamnion laxum Setchell & Gardner

Scagel, 1957
Southern British Columbia and northern Wash.; Oreg.

Callithamnion marshallense Dawson

Dawson, 1960*a*
Bahía Uvita, Costa Rica

Callithamnion pacificum Taylor

Dawson, 1954
Isla Socorro, Revillagigedo Arch.

Callithamnion paschale Børgesen

Dawson, 1957, 1959
Isla San Benedicto, Revillagigedo Arch. ?; Gulf of Calif.

Callithamnion pikeanum Harvey var. *pikeanum*

Scagel, 1957; Dawson, 1959*c*
Vallenar Point, Alaska, to Point Dume, Calif.

Callithamnion pikeanum var. *pacificum* (Harvey) Setchell & Gardner

Scagel, 1957
Shumagin I., Alaska, to Oreg.; Point Mugu, Calif.

Callithamnion ramosissimum Gardner

Gardner, 1927*c;* Dawson, 1949
Santa Catalina I., La Jolla, Calif.

Callithamnion rupicolum Anderson f. *rupicolum*

Smith, 1944; Dawson, 1954
Fort Ross, Calif., to Isla Magdalena, Baja Calif.

Callithamnion rupicolum f. *pygmaeum* Collins in Collins, Holden & Setchell

Collins, Holden & Setchell, 1911 (P.B.A. 1797); Dawson, 1949; Taylor, 1945 (as possibly *C. rupicolum* f. *pygmaeum*)
Santa Catalina I., Calif.; Galapagos Arch.

Callithamnion socorriense Taylor

Dawson, 1954
Isla Socorro, Revillagigedo Arch.

Callithamnion squarrulosum Harvey

Harvey, 1853; J. Agardh, 1876
Golden Gate (San Francisco) Calif.

Callithamnion varispiralis Dawson

Dawson, 1954
Santa Catalina I., Calif.; Bahía Vizcaino, Baja Calif.

Haloplegma mexicanum Taylor

Dawson, 1954
Isla María Magdalena, Nayarit

Pleonosporium abysicola Gardner

Scagel, 1957
Near Friday Harbor, Wash.

Pleonosporium complanatum Taylor

Taylor, 1945
Galapagos Arch.

Pleonosporium dasyoides (J. Agardh) J. B. De Toni

Dawson, 1954, 1959*c*
Tomales Bay, Calif., to Punta Descanso, Baja Calif.

Pleonosporium globuliferum Levring

Dawson, 1957*b*, 1960*a*
Puerto Guatulco, Oaxaca; Golfo de Nicoya, Costa Rica

Pleonosporium kobayashii Okamura

Okamura 1933
Atka I., Aleutian Islands, Alaska

Pleonosporium polycarpum Gardner

Gardner, 1927*b*
La Jolla, Calif.

Pleonosporium pygmaeum Gardner

Gardner, 1927*b*
La Jolla, Calif.

Pleonosporium squarrosum Kylin var. *squarrosum*

Scagel, 1957
Southern British Columbia to Northern Wash.

Pleonosporium squarrosum var. *obovatum* Gardner

Scagel, 1957
Sidney, Vancouver I., British Columbia

Pleonosporium vancouverianum (J. Agardh) J. Agardh

Scagel, 1957
Northern British Columbia to Monterey, Calif.

Griffithsia (?) *anthericephala* Dawson

Dawson, 1954
Isla Guadalupe, Baja Calif.

Griffithsia multiramosa (Setchell & Gardner) Taylor var. *multiramosa*

Dawson 1945*b*, 1954
San Diego, Calif.; Isla Guadalupe; Scammon Lagoon; San Ignacio Lagoon, Baja Calif.; Gulf of Calif.

Griffithsia multiramosa var. *balboensis* Hollenberg

Hollenberg, 1945
Balboa Harbor, Calif.

Griffithsia multiramosa var. *minor* Taylor

Dawson, 1954
Punta Gorda, Baja Calif. del Sur

Griffithsia pacifica Kylin

Scagel, 1957; Dawson, 1954; Dawson, Neushul & Wildman, 1960
Southern British Columbia to southern Baja Calif.; northern Gulf of Calif.; Revillagigedo Arch. ?; Galapagos Arch.

Griffithsia tenuis C. Agardh

Dawson, 1954, 1959
Scammon Lagoon, Baja Calif.; Punta Peñasco, Sonora, to Mazatlán, Sinaloa

Spermothamnion phycophilum Taylor

Taylor, 1945
Galapagos Arch.

Spermothamnion snyderae Farlow

Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Bolinas, Calif., to Isla Magdalena, Baja Calif.; northern Gulf of Calif.

Tiffaniella saccorhiza (Setchell & Gardner) Doty & Meñez

Doty & Meñez, 1960; Dawson, 1954 (as *Spermothamnium saccorhiza*)
Isla Guadalupe; Bahía Vizcaino, Baja Calif.

FAM. DELESSERIACEAE

Caloglossa leprieurii (Montagne) J. Agardh

Taylor, 1945; Dawson, 1957*b*
Golfo Dulce, Costa Rica; Bahía Buenaventura, Colombia; Galapagos Arch.; Bahía San Francisco, Ecuador

Branchioglossum undulatum Dawson

Dawson, 1949, 1960*a*; Dawson, Neushul & Wildman, 1960, 1960*a*
Santa Rosa I., Calif., to Punta Asunción, Baja Calif.; Bahía Santiago, Colima

Branchioglossum woodii (J. Agardh) Kylin

Dawson, 1954, 1957, 1959; Scagel, 1957
Vancouver I., British Columbia, to Bahía Vizcaino, Baja Calif.; Rocas Alijos; Gulf of Calif.

Hypoglossum abyssicolum Taylor

Dawson, 1954
Islas Las Tres Marías, Nayarit; Puerto Culebra, Costa Rica; Isla Gorgona, Colombia; Galapagos Arch.

Hypoglossum attenuatum Gardner

Dawson, 1954
Isla Guadalupe; San Ignacio Lagoon, Baja Calif.; northern Gulf of Calif.

Hypoglossum retusum Dawson

Dawson, 1954; Dawson, Neushul & Wildman, 1960*a*
Isla Cedros; near Punta Eugenio, Baja Calif.

Hemineura (?) *howellii* Taylor

Taylor, 1945
Galapagos Arch.

Membranoptera denticulata (Montagne) Kylin

Kylin, 1924; Setchell & Gardner, 1903 (as *Pteridium spinulosum*)
Bering Sea to Morzhovoi Bay, Alaska

Membranoptera dimorpha Gardner

Scagel, 1957
Queen Charlotte I., British Columbia, to Coos Bay, Oreg.

Membranoptera multiramosa Gardner

Doty, 1947
Oreg. to Monterey, Calif.

Membranoptera platyphylla (Setchell & Gardner) Kylin

Scagel, 1957
Southern British Columbia to Oreg.

Membranoptera setchellii Gardner

Gardner, 1926
Morzhovoi Bay, Alaska

Membranoptera spatulata Dawson

Dawson ,1954
Isla Patos, Sonora

Membranoptera tenuis Kylin

Scagel, 1957
Northern Wash.

Membranoptera weeksiae Setchell & Gardner

Scagel, 1957
Northern Wash.; San Francisco to San Diego, Calif.

Pantoneura baerii (Ruprecht) Kylin

Kylin, 1924
Sitka, Alaska

Pantoneura juergensii (J. Agardh) Kylin

Kylin, 1924
Bering Sea to Unalaska, Alaska

Holmesia californica (Dawson) Dawson

Scagel, 1957
Northern Wash.; San Diego, Calif.

Schizoseris pygmaea Dawson

Dawson, 1954, 1959
Northern Gulf of Calif.

Delesseria decipiens J. Agardh

Scagel, 1957
Prince William Sound, Alaska, to Carmel, Calif.

Delesseria hancockii Taylor

Taylor, 1945
Galapagos Arch.

Platysiphonia clevelandii (Farlow) Papenfuss

Scagel, 1957
Northern Wash. to San Diego, Calif.

Platysiphonia parva Silva & Cleary

Silva & Cleary, 1954; Dawson, 1954
Isla Guadalupe, Baja Calif.

Taenioma perpusillum J. Agardh

Dawson, 1954, 1959, 1960*a*
Gulf of Calif.; Isla Brincanco, Panamá

Erythroglossum californicum (J. Agardh) J. Agardh

Doty, 1947; Dawson, 1958
Oreg.; Monterey to Ventura, Calif.

Erythroglossum intermedium (J. Agardh) Kylin

Scagel, 1957
Vancouver I., British Columbia

Sorella delicatula (Gardner) Hollenberg var. *delicatula*

Hollenberg, 1943
San Pedro, Calif.

Sorella delicatula var. *californica* Hollenberg

Hollenberg, 1943
Southern Calif.

Sorella divaricata (Setchell & Gardner) Hollenberg

Hollenberg, 1943; Smith, 1944 (as *Erythroglossum divaricata*)
Pacific Grove, Calif.

Sorella pinnata Hollenberg

Dawson, 1954
Southern Calif.; Islas San Benito, Baja Calif.; Gulf of Calif.

Grinnellia lanceolata Dawson

Dawson, 1954, 1959*c*
Punta Gorda, Baja Calif. del Sur

Polyneura latissima (Harvey) Kylin

Scagel, 1957; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960, 1960*a*
Northern British Columbia to Punta Eugenio, Baja Calif.

Polyneurella hancockii Dawson

Dawson, 1954
Isla Angel de la Guarda, Gulf of Calif.

Nienburgia andersoniana (J. Agardh) Kylin

Doty, 1947; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Oreg.; Santa Cruz, Calif., to Isla Magdalena, Baja Calif.

Nienburgia borealis (Kylin) Kylin

Scagel, 1957
Southern British Columbia to northern Wash.

Phycodrys ambigua Gardner

Gardner, 1927*a*
Sitka, Alaska

Phycodrys bullata Gardner

Gardner, 1927*a*
Agattu I., to Sitka, Alaska

Phycodrys elegans Setchell & Gardner

Setchell & Gardner, 1937; Taylor, 1945
Galapagos Arch.

Phycodrys pulchra Taylor

Taylor, 1945 (as probably equal to *P. elegans*)
Galapagos Arch.

Phycodrys setchellii Skottsberg

Doty, 1947; Dawson, 1954, 1959*c*
Oreg. to Isla Cedros, Baja Calif.

Pseudophycodrys rainosukei Tokida

Okamura, 1933
Atka I., Aleutian Islands, Alaska

Polycoryne gardneri Setchell

Scagel, 1957
Northern Wash. to Monterey, Calif.

Polycoryne phycodricola Dawson

Dawson, 1954
Isla Cedros, Baja Calif.

Haraldia prostrata Dawson, Neushul & Wildman

Dawson, Neushul & Wildman, 1960*a*
Islas San Benito, Baja Calif.

Anisocladella pacifica Kylin

Smith, 1944; Hollenberg, 1948; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Santa Cruz, Calif., to Bahía Asunción, Baja Calif.

Myriogramme caespitosa Dawson

Dawson, 1949; Dawson, Neushul & Wildman, 1960, 1960*a*
Santa Rosa I., Calif., to Isla Magdalena, Baja Calif.

Myriogramme divaricata Dawson

Dawson, 1954
Isla Ángel de la Guarda, Gulf of Calif.

Myriogramme hollenbergii Kylin

Smith, 1944; Dawson, 1954, 1958
Monterey; La Jolla, Calif.; Isla Magdalena, Baja Calif.

Myriogramme kylinii Taylor

Taylor, 1945
Galapagos Arch.

Myriogramme osorioi Dawson

Dawson, 1954
Isla Patos; Isla Partida, northern Gulf of Calif.

Myriogramme pulchra Gardner

Scagel, 1957
Northern Wash.

Myriogramme repens Hollenberg

Hollenberg, 1945
Point Vicente, Calif.

Myriogramme spectabilis (Eaton) Kylin

Dawson, 1954; Scagel, 1957
Northern Wash. to Socorro, Baja Calif.

Acrosorium (?) *fragile* Taylor

Taylor, 1945
Galapagos Arch.

Acrosorium papenfussii Taylor

Taylor, 1945
Galapagos Arch.

Acrosorium uncinatum (Turner) Kylin

Kylin, 1941; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Southern Calif. to Bahía Santa María, Baja Calif.

Nitophyllum divaricatum Taylor

Taylor, 1945
Galapagos Arch.

Nitophyllum galapagense Taylor

Taylor, 1945
Galapagos Arch.

Nitophyllum mirabile Kylin

Scagel, 1957
Southern British Columbia to northern Wash.

Hymenena cuneifolia Doty

Doty, 1947
Coos Bay, Oreg

Hymenena flabelligera (J. Agardh) Kylin

Scagel, 1957
Southern British Columbia to Carmel, Calif.

Hymenena kylinii Gardner

Doty, 1947
Oreg.; San Francisco to Monterey, Calif.

Hymenena multiloba (J. Agardh) Kylin

Doty, 1947
Oreg. to Carmel, Calif.

Hymenena setchellii Gardner

Scagel, 1957
Hope I., British Columbia, to Carmel, Calif.

Hymenena smithii Kylin

Doty, 1947
Oreg.; Carmel, Calif.

Cryptopleura brevis Gardner

Doty, 1947
Oreg.; Moss Beach, Calif.

Cryptopleura corallinara (Nott) Gardner

Dawson, 1954, 1957, 1959*c*; Dawson, Neushul & Wildman, 1960*a*
San Diego, Calif., to Isla Magdalena; Rocas Alijos, Baja Calif.

Cryptopleura crispa Kylin

Kylin, 1941; Doty, 1947; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Oreg.; Ventura Co., Calif., to Isla Magdalena, Baja Calif.

Cryptopleura dichotoma Gardner

Gardner, 1927
San Pedro, Calif.

Cryptopleura lobulifera (J. Agardh) Kylin

Smith, 1944; Dawson, 1949, 1954, 1959*c*
Tomales Bay, Calif., to Bahía Santa María, Baja Calif.

Cryptopleura ruprechtiana (J. Agardh) Kylin

Scagel, 1957
Sitka, Alaska, to northern Calif.

Cryptopleura spatulata Gardner

Gardner, 1927; Dawson, 1960*a*
Santa Barbara; San Pedro, Calif.; Islas Todos Santos, Baja Calif.

Cryptopleura violacea (J. Agardh) Kylin

Scagel, 1957; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Southern Vancouver I., British Columbia, to near Punta María, Baja Calif.

Botryoglossum farlowianum (J. Agardh) J. B. De Toni

Scagel, 1957 Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960, 1960*a*
Puget Sound, Wash., to Islas San Benito, Baja Calif.

Gonimophyllum skottsbergii Setchell

Scagel, 1957
Friday Harbor, Wash., to San Diego, Calif.

FAM. DASYACEAE

Dasya abyssicola Dawson

Dawson, 1949
San Clemente Is., Calif.

Dasya californica Gardner

Dawson, 1945*b*, 1954
Southern Calif. to Isla Magdalena, Baja Calif.

Dasya eastwoodae Setchell & Gardner

Dawson, 1954
Isla Guadalupe, Baja Calif.

Dasya pedicellata C. Agardh

Dawson, 1954, 1957, 1959
Rocas Alijos; central Baja Calif.; northern Gulf of Calif.

Dasya sinicola (Setchell & Gardner) Dawson

Dawson, 1959
Southern Gulf of Calif.

Dasya stanfordiana Farlow

Taylor, 1945; Dawson, 1954
Isla Guadalupe, Baja Calif.; Islas Tres Marías, Nayarit; Galapagos Arch.

Rhodoptilum densum (G. M. Smith) comb. nov.

Smith, in Smith & Hollenberg, 1943; 217; Smith, 1944; Hollenberg, 1948 (all as *Dasyopsis densa*)
Santa Cruz, Calif., to southern Calif.

Rhodoptilum plumosum (Harvey & Bailey) Kylin

Kylin, 1956; Scagel, 1957 (as *Dasyopsis plumosa*)
Queen Charlotte Sound, British Columbia, to northern Calif.

Pogonophorella californica (J. Agardh) Silva

Hollenberg, 1948; Dawson, 1945*b* (both as *Pogonophora*), 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Santa Barbara, Calif., to Bahía Asunción, Baja Calif.

Heterosiphonia asymmetria Hollenberg

Hollenberg, 1945
Corona del Mar, Calif.

Heterosiphonia densiuscula Kylin

Scagel, 1957
Northern Wash.

Heterosiphonia erecta Gardner, em. Setchell & Gardner

Dawson, 1949, 1954, 1957; Taylor, 1945
Santa Monica, Calif., to Rocas Alijos; Isla Magdalena, Baja Calif.; Guayas, Ecuador

Heterosiphonia laxa Kylin

Scagel, 1957
Southern British Columbia to northern Wash.

Heterosiphonia wurdemannii var. *laxa* Børgesen

Dawson, 1957*b*, 1959
Isla Espíritu Santo, Gulf of Calif.; Golfo de Nicoya, Costa Rica

FAM. RHODOMELACEAE

Polysiphonia acuminata Gardner

Hollenberg, 1942*a*; Smith, 1944
Monterey to La Jolla, Calif.

Polysiphonia bajacali Hollenberg

Hollenberg, 1961
Isla Guadalupe, Baja Calif.

Polysiphonia beaudettei Hollenberg

Hollenberg, 1961
Isla Guadalupe; Scammon Lagoon, Baja Calif.; Isla Socorro, Revillagigedo Arch.; Isla Grande, Guerrero; Bahía Potrero Grande, Costa Rica

Polysiphonia bifurcata Hollenberg

Taylor, 1945; Hollenberg, 1961
Scammon Lagoon, Baja Calif.; Playa Blanca, Costa Rica; Galapagos Arch.

Polysiphonia brodiaei (Dillwyn) Greville

Hollenberg, 1944; Smith, 1944
Sausalito to Santa Monica, Calif.

Polysiphonia confusa Hollenberg

Hollenberg, 1961; Dawson, 1959*c* (as *P. inconspicua*)
Corona del Mar, Calif., to Desembarcadero de Miller, Baja Calif.

Polysiphonia decussata Hollenberg

Hollenberg, 1961; Taylor, 1945
Topanga Canyon, Calif., to near Punta Malarrino, Baja Calif.; Isla Guadalupe; Galapagos Arch.

Polysiphonia ferulacea Suhr

Dawson, 1957
Clipperton I.

Polysiphonia flaccidissima Hollenberg var. *flaccidissima*

Hollenberg, 1961
Laguna Beach, Calif., to Panamá

Polysiphonia flaccidissima var. *smithii* Hollenberg

Hollenberg, 1942*a*; Smith, 1944
San Francisco to San Diego, Calif.

Polysiphonia guadalupensis Setchell & Gardner

Hollenberg, 1961
Isla Guadalupe, Baja Calif.

Polysiphonia hancockii Dawson

Hollenberg, 1961
Cabeza Ballena to San Jose del Cabo, Baja Calif. del Sur

Polysiphonia hendryi Gardner var. *hendryi*

Doty, 1947; Hollenberg, 1961
Cape Arago, Oreg., to Isla Cedros, Baja Calif.

Polysiphonia hendryi var. *gardneri* (Kylin) Hollenberg

Scagel, 1957; Dawson, 1959*c* (both as *P. collinsii*); Hollenberg, 1961
British Columbia to Cabo San Lucas, Baja Calif.

Polysiphonia hendryi var. *compacta* (Hollenberg) Hollenberg

Hollenberg, 1961
Southern Calif. and northern Baja Calif.

Polysiphonia hendryi var. *deliquescens* (Hollenberg) Hollenberg

Scagel, 1957 (as *P. collinsii* var. *deliquescens*); Hollenberg, 1961
Prince William Sound, Alaska, to Oreg.

Polysiphonia hendryi var. *luxurians* (Hollenberg) Hollenberg

Scagel, 1957 (as P. *collinsii* var. *luxurians;* Hollenberg, 1961
Northern Wash.

Polysiphonia homia Setchell & Gardner

Hollenberg, 1961
Isla Guadalupe, Baja Calif.

Polysiphonia howei Hollenberg

Taylor, 1955; Hollenberg, 1958*a*
Bahía de Panamá, Panamá; Bahía Cobita, Colombia

Polysiphonia indigena Hollenberg

Hollenberg, 1958*a*, 1944 (as *P. dichotoma*)
Santa Cruz; San Diego, Calif.

Polysiphonia johnstonii Setchell & Gardner var. *johnstonii*

Dawson, Neushul & Wildman, 1960*a*; Hollenberg, 1961
Santa Catalina I., Calif., to Topolobampo, Sinaloa; Gulf of Calif.

Polysiphonia johnstonii var. *concinna* (Hollenberg) Hollenberg

Hollenberg, 1961
La Jolla, Calif., to Mazatlán, Sinaloa; Gulf of Calif.

Polysiphonia macounii Hollenberg

Scagel, 1957
Southern British Columbia

Polysiphonia masonii Setchell & Gardner

Hollenberg, 1961
Isla Guadalupe, Baja Calif.

Polysiphonia mollis Hooker & Harvey

Dawson, 1959*c*; Scagel, 1957 (both as *P. snyderae*); Hollenberg, 1961; Dawson, 1957; 1957*b*, 1959*b*; Dawson, Neushul & Wildman, 1960
Southern British Columbia to central Mexico

Polysiphonia nathanielii Hollenberg

Hollenberg, 1961
Santa Monica, Calif., to Playa Rosarita, Baja Calif.

Polysiphonia pacifica var. *pacifica*

Doty, 1947; Dawson, 1959*c*; Hollenberg, 1961
Sitka, Alaska, to Islas Coronados, Baja Calif.

Polysiphonia pacifica var. *delicatula* Hollenberg

Hollenberg, 1961
Monterey, Calif., to Bahía Cahuacán, Chiapas; central Gulf of Calif.

Polysiphonia pacifica var. *determinata* Hollenberg

Scagel, 1957
Alaska to central Calif.

Polysiphonia pacifica var. *distans* Hollenberg

Scagel, 1957
Southern British Columbia to Santa Cruz, Calif.

Polysiphonia pacifica var. *disticha* Hollenberg

Hollenberg, 1942*a*; Scagel, 1957; Segi, 1951 (as *P. abscissa*)
Vancouver I., British Columbia, to central Calif.

Polysiphonia pacifica var. *gracilis* Hollenberg

Scagel, 1957
Southern British Columbia to central Calif.

Polysiphonia paniculata Montagne

Scagel, 1957; Dawson, 1959*c*; Hollenberg, 1961; Dawson, Neushul & Wildman, 1960*a*
Port Holmes, British Columbia, to Punta Baja, Baja Calif.; northern Gulf of Calif.

Polysiphonia savatieri Hariot

Hollenberg, 1961; Dawson, 1945*b* (as *P. minutissima*)
Santa Catalina I., Calif., to Isla Guadalupe; Punta Banda, Baja Calif.

Polysiphonia senticulosa Harvey

Scagel, 1957
Southern British Columbia to Monterey, Calif.

Polysiphonia simplex Hollenberg

Hollenberg, 1961; Dawson, 1959*c*
Southern Calif. to Costa Rica; Gulf of Calif.; Revillagigedo Arch.

Polysiphonia sonorensis Hollenberg

Hollenberg, 1961
Guaymas; Empalme, Sonora

Polysiphonia subtilissima Montagne (fide Tseng)

Dawson, 1957*b*, 1959*b*
Costa Rica; Clipperton I.

Polysiphonia urceolata (Lightfoot) Greville

Okamura, 1933; Segi, 1951; Scagel, 1957
Aleutian I., Alaska, to northern Wash.

Tayloriella dictyurus (J. Agardh) Kylin

Kylin, 1956; Dawson, 1954 (as *Bryocladia dictyurus*)
Bahía Petatlán, Guerrero; Pochetti, Oaxaca ?

Bryocladia borealis Dawson

Dawson, 1954
Campo Malarrimo, Bahía Vizcaino, Baja Calif.

Ophidocladus californica (Hollenberg) Kylin

Kylin, 1956; Dawson, 1960*a*; Hollenberg, 1943 (as *Rhodosiphonia*)
Santa Barbara to San Diego, Calif.

Digenia simplex (Wulfen) C. Agardh

Dawson, 1954, 1957*b*, 1959
Gulf of Calif. to Costa Rica

Bryothamnion pacificum Taylor

Dawson, 1954
Bahía Vizcaino, Baja Calif.; Isla María Magdalena, Nayarit

Bostrychia binderi Harvey

Taylor, 1945; Dawson, 1957*b*
Golfo Dulce, Costa Rica; Galapagos Arch.

Bostrichia calliptera (Montagne) Montagne

Taylor, 1945
Panamá; Choco, Bahía Buenaventura; Isla Gorgona, Colombia; Galapagos Arch.

Bostrychia radicans Montagne

Taylor, 1945; Dawson, 1954, 1957*b*; Post 1955 (as *B. radicans* f. *moniliforme*)
Guaymas, Sonora; Barra de Navidad, Jalisco; El Salvador; Golfo Dulce, Costa Rica; Choco, Bahía Buenaventura, Colombia; Galapagos Arch.

Bostrychia simpliciuscula Harvey ex J. Agardh

Dawson, 1957*b*
Golfo de Nicoya, Costa Rica

Bostrychia tenella J. Agardh

Taylor, 1945
Galapagos Arch.

Lophosiphonia macra (Harvey) Falkenberg

Dawson, 1954*c*
Isla San Benedicto, Revillagigedo Arch.

Lophosiphonia mexicana Dawson

Dawson, 1954
Isla Cedros, Baja Calif.; Isla Ángel de la Guarda, Gulf of Calif.; Isla Clarión, Revillagigedo Arch.

Lophosiphonia reptabunda (Suhr) Kylin

Kylin, 1956; Dawson, 1957*b*, 1959*c* (possibly confused with *Ophidocladus*); Scagel, 1957 (as *L. obscura*); Hollenberg, 1958*a* (as *L. obscura*)
Southern British Columbia to northern Wash.; southern Calif. ?; Costa Rica ?

Lophosiphonia scopulorum (Harvey) Womersley

Dawson, 1957*b*, 1959, 1959*c*, 1954 (as *L. villum*); Scagel, 1957 (as *L. villum*)
Southern British Columbia to Isla Magdalena, Baja Calif.; Gulf of Calif.

Brogniartella mucronata (Harvey) Schmitz

Dawson, 1954; Kylin, 1956 (as probably a species of *Micropeuce*)
Isla María Magdalena, Nayarit

Veleroa subulata Dawson

Dawson, 1954
Bahía Tepoca, Sonora

Pterosiphonia arctica Setchell & Gardner

Okamura, 1933; Scagel, 1957
Aleutian I., Alaska, to Puget Sound, Wash.

Pterosiphonia baileyi (Harvey) Falkenberg

Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Crescent City, Calif., to Isla San Roque, Baja Calif.

Pterosiphonia bipinnata (Postels & Ruprecht) Falkenberg var. *bipinnata*

Okamura, 1933; Scagel, 1957
Aleutian I., Alaska, to San Pedro, Calif.

Pterosiphonia bipinnata var. *robusta* (Gardner) Doty

Scagel, 1957
Sitka, Alaska, to Oreg.

Pterosiphonia californica Kylin

Kylin, 1941; Hollenberg, 1948
La Jolla, Calif.

Pterosiphonia dendroidea (Montagne) Falkenberg

Taylor, 1945; Scagel, 1957; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Northern British Columbia to San Jose del Cabo, Baja Calif.; Galapagos Arch.

Pterosiphonia gracilis Kylin

Scagel, 1957
Southern British Columbia to Coos Bay, Oreg.

Pterosiphonia pennata (Roth) Falkenberg

Dawson, 1954
Bahía Tepoca, Sonora

Levringiella gardneri (Setchell) Kylin

Dawson, 1945*c*; Hollenberg 1948 (both as *Stromatocarpus gardneri*); Kylin, 1956
Santa Monica to La Jolla, Calif.

Pterochondria pygmaea (Setchell) Hollenberg

Dawson, 1954; Dawson, Neushul & Wildman, 1960
Southern Calif. to Bahía Asunción, Baja Calif.

Pterochondria woodii (Harvey) Hollenberg

Scagel, 1957; Dawson, 1959*c*; Dawson, Neushul & Wildman, 1960
Vancouver, British Columbia, to Isla Asunción, Baja Calif.

Herposiphonia grandis Kylin

Scagel, 1957
Southern British Columbia to Coos Bay, Oreg.

Herposiphonia rigida Gardner var. *rigida*

Scagel, 1957
Southern British Columbia to Santa Monica, Calif.

Herposiphonia rigida var. *laxa* Setchell & Gardner

Dawson, 1949, 1954
Santa Catalina I., Calif.; Isla Guadalupe, Baja Calif.

Herposiphonia secunda (C. Agardh) Ambronn

Taylor, 1945; Hollenberg, 1948; Dawson, 1957, 1957*b*, 1959, 1959*b*, 1959*c*
Southern Calif. to Isla Jicarita, Panamá; southern Gulf of Calif.; Clipperton I.

Herposiphonia spinosa Dawson

Dawson, 1959
Isla Partida, Baja Calif. del Sur

Herposiphonia subdisticha Okamura

Dawson, 1954; Scagel, 1957 (both as *H. parva*); Dawson, 1954, 1957*b*, 1959, 1960*a*
Northern Wash. to Isla Guadalupe; Islas San Benito, Baja Calif.; Gulf of Calif.; Golfo de Nicoya, Costa Rica

Herposiphonia tenella (C. Agardh) Nägeli

Hollenberg, 1948; Dawson, 1954, 1954*c*, 1957*b*, 1959
Southern Calif. to Bahía Vizcaino, Baja Calif.; Kino, Sonora to Golfo de Nicoya, Costa Rica; Isla San Benedicto, Revillagigedo Arch.

Herposiphonia verticillata (Harvey) Kylin

Coe, 1932; Dawson, 1954, 1959*c*
San Francisco, Calif., to Punta Santa Rosalía, Baja Calif.

Amplisiphonia pacifica Hollenberg

Dawson, 1954; Scagel, 1957; Dawson, Neushul & Wildman, 1960, 1960*a*
Northern British Columbia to near Punta Eugenio, Baja Calif.

Jantinella verrucaeformis (Setchell & McFadden) Kylin

Dawson, 1954 (in part as *J. sinicola*), 1959; Setchell & Gardner, 1930 (as *J. sinicola*)
San Pedro, Calif., to Bahía Vizcaino, Baja Calif.; Isla Clarión, Revillagigedo Arch.; southern Gulf of Calif.

Chondria arcuata Hollenberg

Hollenberg, 1945
Corona del Mar; Laguna Beach, Calif.

Chondria californica (Collins) Kylin

Dawson, 1946 (as *C. cuscutoides*), 1954, 1954*d*, 1959, 1959*c*; Dawson, Neushul & Wildman, 1960
La Jolla, Calif., to Puerto Culebra, Costa Rica

Chondria clarionensis Setchell & Gardner

Dawson, 1954, 1959 (as possibly equal to *C. californica*)
Isla Guadalupe, Baja Calif., Isla Clarión, Revillagigedo Arch.

Chondria dangeardii Dawson

Dawson, 1960*a*
Isla del Rey, Panamá

Chondria dasyphylla (Woodward) C. Agardh

Dawson, 1954, 1959
Bahía Gonzaga to Bahía Agua Verde, Gulf of Calif.

Chondria decipiens Kylin

Smith, 1944; Dawson, 1945*b*, 1954, 1958, 1959, 1959*c*
Santa Cruz, Calif., to Cabo Colnett, Baja Calif. Isla San Pedro Nolasco, Gulf of Calif. ?

Chondria flexicaulis Taylor

Taylor, 1945
Galapagos Arch.

Chondria lancifolia Okamura

Dawson, 1957, 1957*b*
Rocas Alijos, Baja Calif.; Golfo de Nicoya, Costa Rica ?

Chondria nidifica Harvey

Kylin, 1941; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
La Jolla, Calif., to Bahía Asunción, Baja Calif.

Chondria oppositiclada Dawson

Dawson, 1946
La Jolla, Calif.

Chondria pacifica Setchell & Gardner

Dawson, 1954, 1958
Arroyo Hondo, Santa Barbara Co., Calif., to Bahía Tortuga, Baja Calif.

Chondria platyclada Taylor

Taylor, 1945 Dawson & Beaudette, 1960
Costa Rica; Isla Plata, Ecuador

Chondria repens Børgesen

Dawson, 1957*b*
Golfo Dulce, Costa Rica

Chondria secundata (J. Agardh) J. B. De Toni

J. B. De Toni, 1903
Santa Barbara, Calif.

Laurencia clarionensis Setchell & Gardner

Dawson, 1954
Isla Clarión, Revillagigedo Arch.

Laurencia congesta Taylor

Taylor, 1945
Galapagos Arch.

Laurencia crispa Hollenberg

Smith, 1944
Monterey Peninsula, Calif.

Laurencia decidua Dawson

Dawson, 1954*c*
Isla San Benedicto, Revillagigedo Arch.

Laurencia densissima Setchell & Gardner

Setchell & Gardner, 1937
Galapagos Arch.

Laurencia diegoensis Dawson

Hollenberg, 1948; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Carpinteria, Calif., to Punta Baja, Baja Calif.

Laurencia estebaniana Setchell & Gardner

Dawson, 1954
Isla Smith; Isla San Esteban, Gulf of Calif.

Laurencia gardneri Hollenberg

Smith, 1944
Monterey Peninsula, Calif.

Laurencia hancockii Dawson

Dawson, 1954
Bahía Agua Verde, Gulf of Calif.

Laurencia humilis Setchell & Gardner

Dawson, 1954
Isla Clarión, Revillagigedo Arch.

Laurencia intricata Lamouroux

Dawson, 1954
Bahía Petatlán, Guerrero

Laurencia johnstonii Setchell & Gardner

Dawson, 1954
Northern Gulf of Calif.

Laurencia lajolla Dawson

Dawson, 1958
La Jolla, Calif.

Laurencia masonii Setchell & Gardner

Dawson, 1954
Isla Guadalupe, Baja Calif.

Laurencia mediocris Setchell & Gardner

Setchell & Gardner, 1937
Galapagos Arch.

Laurencia multibulba Dawson, Neushul & Wildman

Dawson, Neushul & Wildman, 1960*a*
Off Punta Hughes and Punta Entrada, Isla Magdalena, Baja Calif.

Laurencia obtusa (Hudson) Lamouroux var. *gracilis* Harvey

Taylor, 1945
Galapagos Arch.

Laurencia obtusiuscula Setchell & Gardner var. *obtusiuscula*

Dawson, 1949*a*, 1954, 1959; Dawson, Neushul & Wildman, 1960*a*
Near Punta Eugenio, Baja Calif.; Gulf of Calif. from Guaymas to San Jose del Cabo

Laurencia obtusiuscula var. *corymbifera* Setchell & Gardner, prox.

Taylor, 1945
Galapagos Arch.

Laurencia obtusiuscula var. *laxa* Setchell & Gardner

Dawson, 1959, 1954 (as *L. obtusiuscula*)
Southern Gulf of Calif.

Laurencia oppositoclada Taylor

Taylor, 1945
Galapagos Arch.

Laurencia pacifica Kylin

Smith, 1944; Dawson, 1954, 1959*c*
Pacific Grove, Calif., to Isla Magdalena, Baja Calif.

Laurencia paniculata (C. Agardh) J. Agardh

Dawson, 1954
Bahía Gonzaga; Guaymas to Bahía Agua Verde, Gulf of Calif.

Laurencia papillosa var. *pacifica* Setchell & Gardner

Dawson, 1954, 1959
Isla Guadalupe; southern Gulf of Calif.

Laurencia peninsularis Taylor

Dawson, 1954
Cabo San Lazaro, Baja Calif.

Laurencia richardsii Dawson

Dawson, 1954*c*
Isla San Benedicto, Revillagigedo Arch.

Laurencia scrippsensis Dawson

Dawson, 1954, 1954*c*
La Jolla, Calif., to Isla Magdalena, Baja Calif.; Isla San Benedicto, Revillagigedo Arch.

Laurencia sinicola Setchell & Gardner

Dawson, 1954, 1959
Southern Gulf of Calif.

Laurencia synderae Dawson

Dawson, 1954, 1954*a*
Santa Catalina I.; La Jolla, Calif.; Islas San Benito; Scammon Lagoon; Bahía Vizcaino, Baja Calif.

Laurencia spectabilis Postels & Ruprecht

Scagel, 1957; Dawson, 1959*c*
Sitka, Alaska, to nothern Santa Barbara Co., Calif.

Laurencia splendens Hollenberg

Smith, 1944; Dawson, 1954, 1959*c*; Dawson, Neushul & Wildman, 1960
Santa Cruz, Calif., to Punta Baja, Baja Calif.

Laurencia subdisticha Dawson, Neushul & Wildman

Dawson, Neushul & Wildman, 1960*a*
Islas San Benito, Baja Calif.; Isla Jicarón, Panamá

Laurencia subopposita (J. Agardh) Setchell

Dawson, 1944*a*, 1954; Dawson, Neushul & Wildman, 1960, 1960*a*
La Jolla, Calif., to Punta Eugenio, Baja Calif.

Laurencia turbinata Setchell & Gardner

Setchell & Gardner, 1937
Isla San Martín, Baja Calif.; Galapagos Arch.

Laurencia voragina Taylor

Dawson, 1954
White Friars I., Guerrero

Erythrocystis saccata (J. Agardh) Silva

Smith, 1944 (as *Ricardia saccata*); Silva, 1952; Dawson, 1954, 1954*c*
Pacific Grove, Calif., to Isla Guadalupe, Baja Calif.; Isla San Benedicto, Revillagigedo Arch.

Janczewskia gardneri Setchell & Gardner

Dawson, 1954; Scagel, 1957
Vancouver I., British Columbia, to Cabo Colnett, Baja Calif.

Janczewskia lappacea Setchell

Kylin, 1941; Dawson, 1954
San Pedro, Calif., to Cabo Colnett, Baja Calif.

Janczewskia moriformis Setchell

Setchell, 1914
Santa Monica, Calif.

Janczewskia solmsii Setchell & Guernsey

Dawson, 1954*b*, 1954
Redondo to San Diego, Calif.; Isla Guadalupe, Baja Calif.

Rhodomela larix (Turner) C. Agardh

Okamura, 1933; Scagel, 1957; Dawson, 1958, 1959*c*
Bering Sea to Government Point, Calif.

Rhodomela lycopodioides (Linnaeus) C. Agardh

Okamura, 1933; Scagel, 1957
Aleutian I., Alaska, to northern Wash.

Rhodomela macrantha (Kützing) Setchell

Tokida, 1949
Alaska; British Columbia

Odonthalia aleutica (Mertens) J. Agardh

Okamura, 1933
Aleutian I., Alaska

Odonthalia dentata (Linnaeus) Lyngbye

Setchell & Gardner, 1903; Tokida, 1949
Alaska to Victoria, British Columbia

Odonthalia floccosa (Esper) Falkenberg

Scagel, 1957
Southern British Columbia to Pismo Beach, Calif.

Odonthalia kamtschatica (Ruprecht) J. Agardh

Scagel, 1957
Alaska to Puget Sound, Wash.

Odonthalia lyallii (Harvey) J. Agardh

Okamura, 1933; Scagel, 1957
Alaska to northern Wash.; Oreg. ?

Odonthalia oregana Doty

Doty, 1947
Curry Co., Oreg.

Odonthalia washingtoniensis Kylin

Scagel, 1957
Hope I., British Columbia, to Coos Bay, Oreg.

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Fishes Killed by the 1950 Eruption of Mauna Loa, Part V
Gonostomatidae

MARION GREY[1]

AMONG THE DEEP-SEA FISHES collected at the surface during the Mauna Loa lava flow into the sea in 1950 were 30 small specimens belonging to the family Gonostomatidae. Of the 5 genera and 5 species represented, 2 of the genera (1 of them new) and all of the species (1 or 2 of them new) were hitherto unknown from waters around the Hawaiian Islands. Gosline *et al.* (1954) described the lava flow and the methods of collecting. I am indebted to Dr. Gosline for permission to report on these specimens, and to Dr. Rolf Bolin for relinquishing his prior claim to them.

Gonostoma atlanticum Norman

MATERIAL EXAMINED: 1 specimen, 59.5 mm. in standard length, collected off the Mauna Loa lava flow, Hawaii, by Moore *et al.*, June 3, 1950.

One specimen, 47 mm. in standard length, collected off the Mauna Loa lava flow, Hawaii, by Yamaguchi, June 6, 1950.

Three specimens, 58.5, 54, and 49 mm. in standard length, collected off the Mauna Loa lava flow, Hawaii, by Gosline *et al.*, June 6, 1950.

Counts and measurements given in order of diminishing size, largest specimen first. Dorsal rays 17, 17, 18, 18, 16. Anal rays 28, 29, 29, 28, 28. Pectoral rays 10. Ventral rays 6. Gill rakers on first arch 11 + 6, 11 + 6, ? + 6, —, 11 + 7. Photophores: BR 9; IV 16; VAV 5; AC 19 (partially lost in smallest specimen); IC 40; OA 13.

Per cent of standard length (59.5, 58.5, 54, 49, 47 mm.): depth 16.8, 17.1–17.9, 16.7–17.6, *ca.* 18.3, 18.0; head 24.3, 25.6, 25.0, 24.5–25.5, 25.5; snout 4.2, 4.27–5.12, 4.62, —, 4.25–5.3; orbit 4.2, 4.27, 3.5–4.62, —, 4.25; interorbital width at center of eye 3.36, 3.42–4.27, 3.5–4.62, —, *ca.* 4.25; upper jaw 18.5, 19.6–20.4, 20.4, 19.4–20.4, 20.2–21.2; premaxillary 3.36, 4.27–5.1, 4.62, —, 5.3; toothed portion of maxillary 14.3, 15.4, 15.7, —, 15.9; tip of snout to dorsal origin 58.0, 58.9, 58.4–59.2, 58.1–59.1, 59.5; to anal origin 56.3, 57.2, 56.5–57.4, 56.1, 56.4; to ventral bases 46.2, 48.6, 46.2, 47.8, 46.7; distance between anal origin and caudal base 41.1–42.0, 42.7, 41.6, 42.7, 42.5; between last anal ray and caudal base *ca.* 10.1, *ca.* 10.2, 10.2, —, 10.6; between last dorsal ray and caudal base *ca.* 23.5, *ca.* 22.2, 22.2–23.1, —, *ca.* 23.4; between inner insertion of ventral and origin of anal *ca.* 8.4, 9.4, 7.4–8.3, —, *ca.* 7.45; least depth of caudal peduncle 5.8–6.7, 5.97–6.83, *ca.* 5.5, —, 6.38; dorsal base 16.8, *ca.* 17.1, 17.6, —, *ca.* 17.0; anal base 31.9, 32.4, 33.3, —, *ca.* 32.0; pectoral length —, 17.1, 16.7, —, 12.75; ventral length *ca.* 7.56, 6.83, 7.4, —, 6.38.

Skin partially lost in all specimens. Only a few scales remaining, mostly over photophores, but well-preserved scale pockets indicating that back and tail, at least, were fully clothed with large, thin, cycloid scales. Pectoral fins reaching as far as 12th or 13th IV photophore. Ventral fins reaching anus. Most specimens with 13 long teeth on maxillary (only 9 or 10 in 2 specimens reported by me in 1960 from the Marshall Islands) and apparently no posterior pterygoid teeth. Three largest specimens with 3 palatine teeth, increasing in size posteriorly. A small reflector present behind ORB in only 1 specimen (47 mm.). Only two largest with small glands visible below OA. All 5 specimens with a single pale yellowish infracaudal gland at base of posterior procumbent caudal rays; possibly a second one originally existed anterior to it. Two well-developed supracaudals with the outward appearance of large photophores, being surrounded on sides and lower surface by blackish brown pigment.

Color blackish brown, head and abdomen darker, cheeks silvery or iridescent and with black puncticulations, peritoneum black, oper-

[1] Chicago Natural History Museum, Chicago, Illinois. Manuscript received December 19, 1960.

cular linings brown, inside of mouth pale anteriorly and brown posteriorly.

Largest specimen (abdomen damaged), a female with large ovaries.

Counts and measurements are in close agreement with those found in published descriptions of this species. The body depth is possibly somewhat greater in Hawaiian specimens and the count, in one, of 11 + 7 gill rakers is unique.

These specimens represent the second Pacific record of *G. atlanticum*. The first capture was in the Marshall Islands area (Grey, 1960). The species is probably more widely distributed in the central portions of the Pacific Ocean than is known at present.

Cyclothone sp.

MATERIAL EXAMINED: 3 specimens, standard length *ca.* 20.5, *ca.* 23, and *ca.* 23.5 mm., collected off the Mauna Loa lava flow, Hawaii, by Moore *et al.*, June 3, 1950.

Specimens all in poor condition; following characters common to all: first VAV very close to ventral base, anus directly below it; VAV evenly spaced; color pale brownish, abdomen darker, myomeres outlined in darker pigment; on 1 specimen a shred of skin with a few black spots remaining, its original position on body not determinable; 2 narrow vertical brown bars at extreme end of caudal peduncle, 1 above mid-line and 1 below mid-line; dashes of internal pigment at end of caudal peduncle; a series of 6 internal brown spots along base of dorsal fin and 18 along anal base; ventral portion of body between ventral and anal fins, below musculature, entirely colorless and transparent, the VAV photophores situated in this region; branchiostegal membrane with a narrow brown line at base and a broken line of brown pigment on edge, otherwise colorless; a bar of brown pigment curving down from pectoral base and extending forward on isthmus.

Specimen *ca.* 23.5 mm.: BR 8; VAV 4, possibly only 3 (fourth at first anal ray). IV, AC, and OA all lost or damaged. Maxillary teeth subequal, becoming gradually larger posteriorly, first one not larger than those immediately behind it.

Specimen *ca.* 23 mm.: BR 8, IV 13. VAV 4, possibly only 3 (fourth at first anal ray). AC and OA mostly lost. Dorsal rays probably 12, anal rays probably 19.

Specimen *ca.* 20.5 mm.: BR 7. IV and VAV mostly lost. AC 9 or 10, last one on caudal base. Last two VAV present, last at anal origin; if this photophore belongs to the AC series, the total number is 10. Gill rakers on first arch 9 + 1 + 3 = 13, only 1 in angle. Vomer toothless. Palatines and pterygoids each with 3 microscopic teeth. Ventral fins undamaged, reaching to or slightly past anal origin.

Both the poor condition of the Hawaiian specimens and the uncertain taxonomic status of species of the genus *Cyclothone* Goode and Bean prevent positive identification of these specimens. They are allied to *C. signata* Garman and *C. alba* Brauer (pale coloration, a single gill raker in the angle of the first arch, no vomerine teeth) and are possibly identical with *C. alba*. However, *C. alba* was described with an AC count of 12 or 13, similar to that of *C. signata*, and the AC number is only 9 or 10 on the only Hawaiian specimen on which these photophores are preserved. The total number of gill rakers on the first arch is similar in all 3 forms, 13 in the 1 Hawaiian specimen on which they can be counted, 14–15 in *C. signata* and *C. alba*. *C. alba* and the Hawaiian specimens have 7–8 BR photophores, in contrast to the 9 or 10 of *C. signata*. Both the first VAV photophore and the anus of the Hawaiian specimens are extremely close to the ventral bases. In *C. alba* these were figured by Brauer (1906: 80, fig. 30) as being placed somewhat more posteriorly. However, in specimens examined from the Atlantic (Florida), probably identical with *C. alba*, the first VAV is also closer to the ventral bases than shown in Brauer's figure and this character may be a variable one.

Although it is no surprise to learn that a light-colored *Cyclothone* inhabits Hawaiian waters, the only species of the genus hitherto reported from the area have been the dark-colored forms *C. atraria* Gilbert and *C. canina* Gilbert.

Araiophos, NEW GENUS

TYPE SPECIES: *Araiophos gracilis*, new species.

Eye normal, large. Snout shorter than orbit. Interorbital width at center of eye less than diameter of orbit or length of snout. Mouth

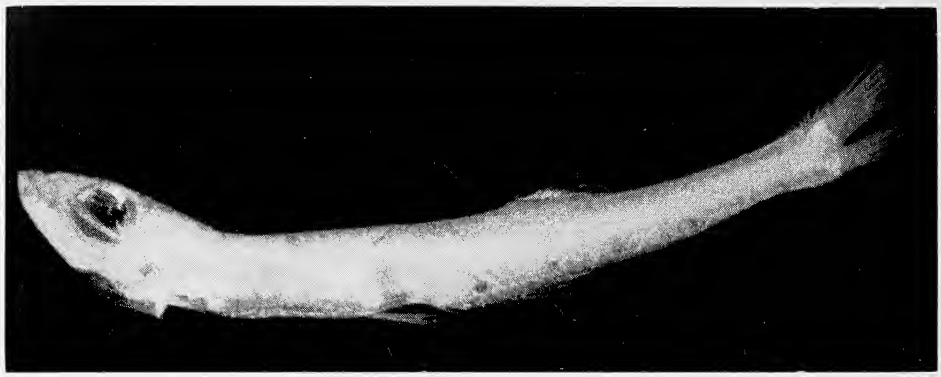

FIG. 1. *Araiophos gracilis,* holotype, standard length 34 mm.

moderate, oblique; edge of premaxillary straight, its angle oblique; toothed edge of maxillary slightly convex, reaching beyond middle of eye but not as far as its posterior margin. Premaxillary about half as long as toothed portion of maxillary. Angle of preopercle almost vertical. All teeth minute, not numerous, uniserial in upper jaw; lower jaw with an outer row of 3–4 teeth anteriorly. Presence or absence of teeth on vomer, palatines, pterygoids, and tongue not determinable. Gill rakers on first arch $15 + 3 = 18$ (1 specimen), 2 in angle. Minute (microscopic) clusters of spines on inner edge of first gill arch. Presence or absence of pseudobranchiae not determinable. No evidence of scales. Anus about half-way between ventral bases and anal origin or slightly nearer the former. Head and trunk about equal in length to tail or slightly shorter. Origin of dorsal fin well behind middle of body length. Anal origin and ventral bases well ahead of dorsal origin. Adipose fin present. ORB 1, in front of eye, close to premaxillary. OP 1 (lower posterior), level with end of maxillary. SO absent. BR (6). No additional photophores on head. Body with a single row of photophores; photophores present on isthmus. IV (2) on isthmus, + (3) + 4 + (2) = 11. VAV (4–5). AC (2) + 3–4 + (2) = 7–8. IC 22–23. No additional photophores and no luminous tissue on body as far as known. Fin rays: dorsal 13–14, anal 28–29, pectoral (15?) 16–17, ventral 6. Branchiostegal rays 8, no spines at bases. Number of vertebrae unknown.

Araiophos differs distinctly from all other maurolicid genera in the reduced number of photophores. Only in the BR count of 6 and the VAV count of 4 or 5 is it similar to others (*Valenciennellus* Jordan and Evermann also has 4 or 5 VAV and several genera have 5). The small number of photophores might be a juvenile character and the absence of photophores between the isthmus and the posterior end of the pectoral base (where in some species they are known to develop late), the absence of 2 of the OP, and the small size of the ORB, give support to the possibility that all of the specimens studied are young. On the other hand, although the specimens range in standard length from a little over 21 mm. to 34 mm., the number and relative size of the photophores are identical in all. If more were to develop, on the body at least, one would expect to find the smallest specimen differing somewhat from the largest. The presence of gonads is also significant and the obvious implication is that *Araiophos* provides another example of neoteny among fishes. Even were the specimens still juvenile they could not be shown to belong to any known genus. Only in *Maurolicus* Cocco is the dorsal fin situated so far behind the middle of the body length; and the Hawaiian specimens cannot belong to *Maurolicus,* in which the developmental stages are well known and which has acquired all of the meristic characters of the adult at a length of about 20 mm. Nor is it likely that the Hawaiian specimens represent a metamorphosis stage of some known genus; as far as we know the development of maurolicid genera is direct and none are known to undergo a metamorphosis

stage with changes in body form or fin positions.

An attempt to modify the diagnosis of one of the known genera to accept this new form has been unsuccessful. Several characters align it with *Thorophos* Bruun and *Neophos* Myers: relative positions of dorsal and anal origins; number of gill rakers; elongate body form; IV photophores on isthmus straight, none curving upward toward pectoral base; VAV not reaching anal origin. The lack of OA photophores, if not a juvenile character, is an additional point of resemblance between the new genus and *Neophos,* which has only 1 OA. However, in both *Thorophos* and *Neophos* the angle of the gape anteriorly is much more acute than that of *Araiophos,* and in *Neophos* and *Thorophos* the gape is wider, the maxillary reaching to or beyond the posterior margin of the eye (only slightly past the middle of the eye in *Araiophos*). In fin ray counts *Araiophos* is closest to *Argyripnus* Gilbert and Cramer, and to *Maurolicus;* and only in the latter, among maurolicid genera, is the dorsal origin situated well behind the middle of the body length as it is in *Araiophos.*

Derivation of name: *araios,* Gr., 'few'; *phos,* Gr., 'light.'

Araiophos gracilis, new species
Figs. 1–3

HOLOTYPE: Standard length 34 mm., collected off the Mauna Loa lava flow, Hawaii, by Gosline *et al.,* June 6, 1950.

PARATYPES: 9 specimens, standard length 30.5, 24, and 23 mm. (3 specimens); length from tip of snout to base of caudal fin 31.5, 28, 27.5, and 26.5 mm. (5 specimens, lower jaws broken), and *ca.* 21 mm. from nape to base of caudal fin (1 specimen, head lacking), collected off the Mauna Loa lava flow, Hawaii, by Moore *et al.,* June 3, 1950.

Dorsal rays 13–14 (holotype 14). Anal rays 28–29 (holotype 29). Pectoral rays 16–17 (holotype 16, possibly only 15). Ventral rays 6. Branchiostegal rays 8. Gill rakers on first arch 15 + 3 = 18 (holotype only), 2 in angle.

Measurements of holotype expressed in per cent of the standard length (34 mm.), followed in parentheses by similar measurements of 2 specimens 31.5 mm. from tip of snout to caudal base and 30.5 mm. in standard length: depth 13.2 (12.7, 13.1–14.7); head *ca.* 22.1 (—, 22.9); snout 5.87 (—, 6.55); orbit 8.8

FIG. 2. *Araiophos gracilis,* holotype, ventral view.

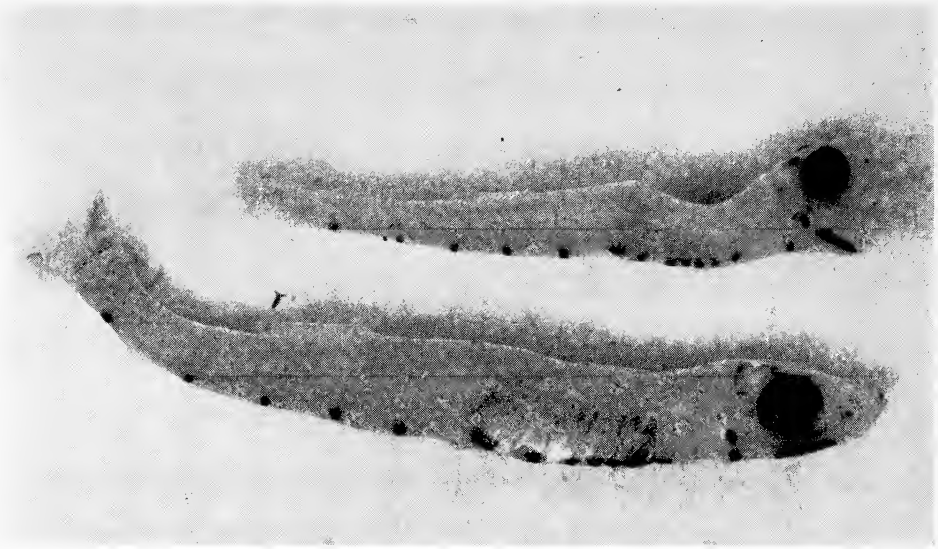

FIG. 3. *Araiophos gracilis*, paratypes, standard length 30.5 and *ca.* 23 mm.

(7.87, 6.55–8.19); interorbital width at center of eye 4.41 (4.73, *ca.* 4.9); upper jaw 13.2; premaxillary *ca.* 4.41; toothed portion of maxillary 8.8; distance between tip of snout and dorsal origin 57.3 (55.2, 57.3), anal origin 48.5 (46.6–47.3, *ca.* 49.0, and in a specimen 28 mm. long from snout to caudal 48.2–50.0), ventral base *ca.* 44.1 (*ca.* 39.4, 44.1); distance between first anal ray and base of middle caudal rays 51.4 (52.0, 49.0, and in a specimen 28 mm. long from snout to caudal 50.0), last anal ray and base of middle caudal rays *ca.* 11.7 (11.0, 14.7–16.4), last dorsal ray and base of middle caudal rays 27.9 (*ca.* 28.4, *ca.* 26.2), last dorsal ray and adipose fin 4.41 (6.3, —), ventral bases and anal origin 5.87 (4.73, 4.9); least depth of caudal peduncle 5.87 (6.3, 4.9–6.55); dorsal base 11.7 (14.2?, 11.5–13.1); anal base 38.2 (39.4, 31.1–32.8); adipose base 2.94 (6.3, —, and in a specimen 23 mm. in standard length 4.34–6.52).

Specimens all damaged to some extent, especially in head and abdominal regions; both eyes of holotype lost, this specimen otherwise in fair condition.

Body elongate, slender, compressed but with ventral surface flat between the second single abdominal IV photophore and the VAV group. No scales or scale pockets remaining. Pectoral fins of holotype reaching half-way between pectoral and ventral bases; bases broadly pedunculate. Ventral fins of holotype reaching anal origin. Adipose fin with a relatively long base; very fragile and easily lost, leaving no trace (absent on 2 specimens, tearing loose on a third, possibly incomplete on holotype); its origin above a vertical from the third single AC photophore, above end of anal fin.

Specimens too small and fragile to determine presence or absence of pseudobranchiae.

Teeth rather sparse, visible only under magnification, their presence or absence on vomer, palatines, pterygoids, or tongue impossible to determine but 1 specimen with a few minute teeth on roof of mouth anteriorly.

Photophores as in generic diagnosis. ORB minute, close to premaxillary. The single OP double, relatively large. Only (2) small IV on isthmus posteriorly, well separated from abdominal IV (no photophores between isthmus and posterior end of pectoral base); abdominal IV commencing just behind pectoral base, organs of groups (first 3 and last 2 organs) small, the 4 single organs much larger, well separated from one another. VAV occupying only anterior half of space between ventrals and anal, the individual organs very small; anus below last, thus about half-way between ventral bases and anal

origin or slightly nearer the former; number usually (4), two specimens with (4) on one side and (5) on the other, holotype with (4) on both sides. First group of AC (two organs) above fifth to seventh anal rays, last group (two organs) behind anal fin but remote from caudal base; single organs much larger than individual organs of groups; number of single organs usually 3, 3 specimens with 3 on one side and 4 on the other, holotype with 3 on both sides.

Visible inside flattened belly of most specimens are two long, narrow, whitish or yellowish masses with the appearance of testes, extending forward to third or fourth single IV photophore. In addition to these structures at least 4 specimens (24, 27.5, 27.5, 31.5 mm.) also with ovaries; eggs minute except in 24 mm. specimen, in which the ovaries are relatively large and contain eggs of different sizes.

Color in alcohol yellowish, abdomen darker. Minute brown puncticulations along mid-line on tail, and outlining myomeres of tail. A narrow vertical brown bar at extreme end of caudal peduncle. Some specimens with a short series of minute brown spots along anal base between first AC group and second single AC. Sparse brown pigment on top of head. A few minute brown spots on caudal rays, fins otherwise colorless. Inner bronzy iridescence and a few relatively large black chromatophores visible through abdominal wall laterally.

Danaphos oculatus (Garman)

MATERIAL EXAMINED: 7 specimens, 2 31.5 and *ca.* 39 mm. in standard length, others slightly shorter but too damaged to measure, collected off the Mauna Loa lava flow, Hawaii, by Moore *et al.,* June 3, 1950.

Two specimens, standard length 36.5 and *ca.* 36.5 mm., collected off the Mauna Loa lava flow, Hawaii, by Gosline *et al.,* June 6, 1950.

One specimen, standard length 33 mm., collected off the Mauna Loa lava flow, Hawaii, by Yamaguchi, June 6, 1950.

Dorsal rays 6 (4 specimens). Anal rays (23?) 24–25 (6 specimens). Pectoral rays *ca.* 18 and *ca.* 16 (2 specimens), upper 7 or 8 rays longer and much heavier than others, lowermost rays small and fine. Gill rakers on first arch 10–11 + 1 + 2 = 13–14 (2 specimens), only 1 in angle.

Measurements of 2 specimens expressed in per cent of the standard length (36.5 and 33 mm.): depth 23.3, 21.2; head 23.3–24.6, 24.2; snout 5.47, 4.54; orbit (both vertical and horizontal) 8.2, 7.55; interorbital width too narrow to be measured accurately; upper jaw —, 15.1–16.6; premaxillary 8.2–9.6. 7.55; toothed portion of maxillary 9.6–10.95, 9.06; tip of snout to dorsal origin 34.2, 34.8; to anal origin 46.5, 45.4–46.9; to ventral base *ca.* 41.0, 37.8–39.3; distance between first anal ray and base of middle caudal rays 52.0, 56.0–57.5; between last anal ray and base of middle caudal rays 8.2–9.6, 7.55; between last dorsal ray and middle caudal rays *ca.* 60.2, 53.0; least depth of caudal peduncle *ca.* 6.85, 7.55; dorsal base *ca.* 4.1, *ca.* 4.54; anal base *ca.* 43.8, 46.9; length of pectoral fin 24.6, 24.2–25.7; length of ventral fin 8.2–9.6, 9.06–10.6.

A few large, round, thin scales remaining on several specimens. Anus below third VAV, slightly nearer anal fin than ventral bases. Dorsal base very short. Anal origin close behind a vertical from last dorsal ray. No adipose fin. Pectorals, when complete, extending as far as third VAV photophore. Ventrals, when complete, reaching slightly past anal origin. Ventral bases below dorsal fin.

Photophores: No upper OP. BR (6). IV complete on only 2 specimens; (3) + (4) on isthmus, organs of first group smaller than those of second group; abdominal group 11, in 1 specimen the first one separate, connection of others not determinable; abdominal series of a second specimen separated thus: 1 + (2) + (8), the gland joining the (2) obvious on outer surface of body, the (8) seen through damaged abdomen to be joined to one another by a narrow gland, and each organ also joined to its counterpart on other side of body; total IV 17–18. VAV (5) in all 10 specimens. AC (3) + 15 + (4) + 1 = 23 in 5 specimens, (4) + 15 + (4) + 1 = 24 in 1 specimen, (3) + 14 + (4) + 1 = 22 in 1 specimen, (3) + 16 + (4) + 1 = 24 in 1 specimen, and 1 specimen with (3) + 16 + (4) + 1 = 24 on one side, (3) + 17 + (4) + 1 = 25 on other side; damaged in 1 specimen. OA (2) + 4 = 6, complete on only 1 specimen.

In alcohol, color of tail and back whitish, abdomen and head, excepting the colorless snout, blackish. Body wall along most of anal base colorless and transparent. End of caudal peduncle blackish. A series of about 28 black spots running from nape almost to caudal base.

Two specimens contain ovaries, the eggs larger in one than in the other.

D. oculatus has not been reported previously from the Hawaiian Islands although it is known to inhabit adjacent parts of the North Pacific, as well as the eastern Pacific from off Lower California to Monterey Bay.

Argyripnus atlanticus Maul
Figs. 4, 5

MATERIAL EXAMINED: 2 specimens, standard length 27 or 27.5 mm. and 35.5 mm., collected off the Mauna Loa lava flow, Hawaii, by Moore *et al.*, June 3, 1950.

Smaller specimen in poor condition; head, tail, and abdomen severely damaged; adipose fin, latter part of anal fin, last group of AC photophores, and isthmus IV mostly lost; abdominal IV damaged. Dorsal rays 12. Anal rays *ca.* 12 in front of AC group of five photophores. Pectoral fins short and fleshy, rays discernible under magnification but not clearly enough to be counted. Gill rakers on first arch 19 + 5 = 24 on left side, 19 + 6 = 25 on right side, 2 in angle. Depth 5–5.5 mm. Head and trunk shorter than tail, distance between snout and anal origin *ca.* 12–12.5 mm. and between first anal ray and base of middle caudal rays 15 mm. Anal origin below about fourth dorsal ray. BR (6). IV on isthmus (6) on one side, apparently straight, not curving upward posteriorly; abdominal IV (10), hanging loose from body, possibly incomplete. First VAV-AC group (14), probably not fully developed, first 6 or 7 in front of anal fin and larger than remainder. Middle group of AC (5). OA lost on one side of body, (2) on other side, remainder probably still undeveloped. Color in alcohol yellowish; upper half of body with a double series of small black chromatophores from nape to tail and a third, incomplete, row running posteriorly from above anal origin.

Larger specimen, 35.5 mm., in fairly good condition although difficult to measure, being bent. A few large, thin, cycloid scales remaining on back and sides. Dorsal rays 11. Anal rays 15 + 10 = 25, a short space filled with membrane below third and fourth organs of the AC group of (5), separating the two groups of rays. Pectoral rays 18. Gill rakers on first arch 19 + 6 = 25, 2 in angle.

Measurements in millimeters: depth 8; head 11; snout 2–2.5; orbit *ca.* 4; interorbital width at center of eye 2–2.5; upper jaw 7–7.5; premaxillary 3–3.5; toothed portion of maxillary 4–4.5; tip of snout to dorsal origin *ca.* 17, to anal origin 15.5, to ventral base *ca.* 12.5–13; distance between first anal ray and base of middle caudal rays 18.5–19, last anal ray and base of middle caudal rays *ca.* 6.5, last dorsal ray and base of middle caudal rays *ca.* 15; least depth of caudal peduncle 2.5–3; dorsal base 3.5–4; anal base *ca.* 11.5; pectoral length 6.5–7; adipose base 1.5; distance between VAV-AC group of photophores and group of (5) 3.5

FIG. 4. *Argyripnus atlanticus*, standard length 35.5 mm.

FIG. 5. *Argyripnus atlanticus*, standard length 35.5 mm., ventral view.

and between group of (5) and posterior AC group 3.5–4.

Premaxillary more than half as long as toothed portion of maxillary. Maxillary reaching a vertical from posterior margin of eye. Head and trunk shorter than tail. Anal origin slightly in advance of dorsal origin, which is above a vertical from about third anal ray. Adipose fin well developed, its origin above a vertical from just behind AC group of (5). Pectoral fin long, nearly reaching anal origin. Ventrals inserted well in advance of dorsal origin, ends of rays broken.

BR (6). IV (6) + (11) = 17, first organ of abdominal group directly below last organ of isthmus group, which curves upward posteriorly; individual organs of first group slightly larger than those of abdominal group. VAV-AC (21) + (5) + (17) = 43, first 7 in front of anal fin and larger than remainder, upward curve over anal fin low and gradual. IC 60. OA (2) + 3 = 5 on left side, no damage apparent, probably not fully developed; ? + 4 on right side, first organs lost but gland remaining (possibly contained 2–3 photophores).

Color in alcohol yellowish; diffuse brown pigment on caudal peduncle and nape; 3 irregular series of small black chromatophores from nape to caudal.

These two little fishes are considerbly smaller than any specimens of the genus *Argyripnus* previously reported and provide the first scant evidence of developmental changes. The larger one possibly possesses all adult characters but it seems more likely that the OA are still incomplete and that a few of the organs of the first VAV-AC group have not yet developed. One or 2 additional organs may also appear in the last group of AC, which in this little fish begins directly behind the anal fin. In all other specimens of *Argyripnus* seen or figured there are 2 to 4 of these photophores above the end of the anal fin.

Characters of the smaller specimen suggest that the middle group of 5 AC develops relatively early and that of the anterior VAV-AC group the organs in front of the anal fin appear first. In the last group of AC the posterior organs are apparently first to appear. The OA develop late, probably being still incomplete on the 35.5 mm. specimen. If the isthmus IV are actually straight on the small damaged fish, as they appear to be, the displacement upward of the posterior organs would occur after the species reaches a

standard length of about 27 mm. and before it attains 35 mm. An additional juvenile character of the smaller specimen is the short, fleshy pectoral fin.

The larger of the 2 Hawaiian specimens differs from all others of the genus *Argyripnus* in two rather important characters, the position of the anal origin in front of the dorsal origin, and the abdominal count of 11 IV. The IV photophores number (6) + (10) = 16 in almost all known specimens of the genus, the only exceptions being found on 2 western Atlantic specimens in which the counts are (6/7) + (10) = 16/17 and (6) + (9/10) = 15/16. Both of the Hawaiian specimens are otherwise very close to, and probably identical with, *A. atlanticus* Maul, a species hitherto known only from the North Atlantic. In Pacific species (*A. ephippiatus* Gilbert and Cramer, *A. iridescens* McCulloch, and an unrecorded specimen from the Philippines) the anal origin is situated below the end of the dorsal fin. In *A. atlanticus* it is below the anterior rays of the dorsal and the anal origin of the younger Hawaiian specimen is similar. The fact that the two little Hawaiian fishes differ from one another in this character suggests that the anal position may be somewhat variable. In meristic characters these specimens differ from *A. atlanticus* only in the number of photophores in the first VAV-AC group and, as noted above, these photophores are probably not fully developed on the Hawaiian fishes. If a few more photophores are still to appear in this series, both the VAV-AC and the IC counts would be within the range of the same counts of *A. atlanticus*. Evidence that a few more photophores actually are present in the adult is shown by the fact that the distance between the AC groups is proportionately greater than in any other specimens of the genus known (see Table 3).

These specimens are also like *A. atlanticus* and unlike other species in the lower and less abrupt curve in the VAV-AC series above the front of the anal fin. Their more slender bodies can certainly be attributed to their youth and the relative lengths of the trunk and tail probably also change with age. Both of the young Hawaiian fishes have a proportionately longer tail, shorter trunk, and shorter distance between the snout and ventral bases than are found in older specimens from either the Atlantic or Pacific oceans.

TABLE 1

MERISTIC CHARACTERS OF *Argyripnus* SPECIES

SPECIMENS	STANDARD LENGTH	DORSAL RAYS	ANAL RAYS	PECTORAL RAYS	VENTRAL RAYS	GILL RAKERS ON FIRST ARCH
A. atlanticus, juv. Hawaii	27–27.5	11–12	—	—	—	19+5–6=24–25
A. atlanticus, juv. Hawaii	35.5	11	15+10=25	18	—	19+6=25
A. atlanticus, type[1] eastern Atlantic	56	12	—=27	19	7	17+7=24
A. atlanticus western Atlantic	55–71	11–12	13–15+(8)9–10=22–27	(16)17–19	6–7	17–19+6–7=22–26
A. ephippiatus Hawaii	72	12	12+12=24	15	6?	13–14+5=18–19
A. ephippiatus, type Hawaii	75	11	11+11=22	15	—	14+5=19
A. ephippiatus Hawaii	80	11–12	—	15	—	13+5–6=18–19
A. iridescens[2] Australia	90–135	12–14	—=24–25	16–17	7	16+?=?
Argyripnus sp. Philippines	82	12	13+12=25	17	7	12+4=16

[1] Data from Maul, 1952: 56.
[2] From McCulloch, 1926: 169, and Norman, 1930: 299.

TABLE 2

PHOTOPHORE COUNTS OF *Argyripnus* SPECIES

SPECIMENS	STANDARD LENGTH	IV	VAV+ FIRST GROUP OF AC	POSTERIOR AC GROUP	VAV[4] +AC TOTAL	IC	OA
A. atlanticus, juv. Hawaii	27–27.5	—	(14)	—	—	—	(2)
A. atlanticus, juv. Hawaii	35.5	(6)+(11)=17	(21)	(17)	43	60	(2)+3=5
A. atlanticus, type[1] eastern Atlantic	56	(6)+(10)=16	(28)	(18)	51	67	7
A. atlanticus western Atlantic	55–71	(6/7)+(9/10)= 15–17[3]	(24–28)	(16–18)	46–51	62–67	(3–4)+3–4=7
A. ephippiatus Hawaii	72	(6)+(10)=16	(20)	(14)	39	55	(5)+2=7
A. ephippiatus, type Hawaii	75	(6)+(10)=16	(19)	(14/15)	38/39	55/56	(5)+2=7
A. ephippiatus Hawaii	80	—	—	—	—	—	(5)+2=7
A. iridescens[2] Australia	90–135	(6)+(10)=16	(20–21)	(12–14)	37–40	53–56	7
Argyripnus sp. Philippines	82	(6)+(10)=16	(18)	(12)	35	51	(5/6)+(1/2)= 7

[1] From Maul, 1952: 56.
[2] See footnote to Table 1.
[3] IV usually (6)+(10)=16; 7 in isthmus group on one side of 1 specimen only and 9 in abdominal group on one side only of a second specimen.
[4] Including middle AC group, which is always (5).

SPECIES OF *Argyripnus*

Meristic characters and some body proportions of a number of specimens of *Argyripnus* are shown in Tables 1–3. In addition to the young specimens reported here the following have been examined: *A. ephippiatus* Gilbert and Cramer, holotype, USNM no. 47708, "Albatross" sta. 3472; and two specimens, USNM no. 126079, Hawaii, "Albatross," 1902, exact data lacking (probably the specimens reported in 1905 by Gilbert). *Argyripnus* sp., USNM no. 135402, Philippines, "Albatross" sta. 5542, vicinity of northern Mindanao, 8° 48′ 30″ N., 123° 35′ 30″ E., 200 fathoms (366 m.), 1 specimen, hitherto unreported. *A. atlanticus* Maul, "Oregon," western Caribbean Sea, 1 specimen (Grey, 1960: 67); and 13 hitherto unreported specimens taken off Puerto Rico ("Oregon" sta. 2644, 2645, 2646) and north of the Bahamas "Combat" sta. 235).

Specimens of *Argyripnus* are too scarce in museum collections to allow a determination of the number of species contained in the genus but are numerous enough to show that at least 2 distinct species exist. It is equally clear that each of these 2 forms is variable but the extent and limits of the variation are not determinable. The eastern Atlantic form of *A. atlanticus*, represented by a single specimen, differs from western Atlantic specimens in having a few more anal rays, more posteriorly situated dorsal and anal fins, and a smaller mouth. *A. atlanticus* also inhabits the Pacific at Hawaii as shown above.

The second distinct form of the genus has been found so far only in the Pacific, at Hawaii, the Philippines, and Australia. As shown in Tables 1–3 these Pacific specimens show variation that may indicate specific distinction. *A. ephippiatus* Gilbert and Cramer, from Hawaii, has fewer pectoral rays than other Pacific specimens. *A. iridescens* McCulloch, from Australia, is deeper bodied than other Pacific speci-

TABLE 3

PROPORTIONS OF *Argyripnus* SPECIES EXPRESSED IN PER CENT OF STANDARD LENGTH

SPECIMENS	STANDARD LENGTH	DEPTH	HEAD	SNOUT	ORBIT	UPPER JAW
A. atlanticus, juv. Hawaii	27–27.5	18.0–20.4	—	—	—	—
A. atlanticus, juv. Hawaii	35.5	22.5	30.9	5.62–7.02	*ca.* 11.3	—
A. atlanticus, type[1] eastern Atlantic	56	26.3	30.0	—	—	—
A. atlanticus western Atlantic	55–71	23.2–*ca.* 27.6	*ca.* 28.7–*ca.* 31.9	*ca.* 5.0–6.8	10.5 to 12.1–12.9	19.0 to 20.4–21.2
A. ephippiatus Hawaii	72	—	—	—	—	—
A. ephippiatus, type Hawaii	75	26.0	*ca.* 32.0	6.65–7.32	12.0	23.3
A. ephippiatus Hawaii	80	25.6	26.2	*ca.* 6.86	13.7	22.5–25.1
A. iridescens[2] Australia	90–135	29.6	30.6	6.8	11.65	—
Argyripnus sp. Philippines	82	26.2	34.7–35.3	6.7–7.3	12.8	23.2

SPECIMENS	SNOUT TO DORSAL ORIGIN	SNOUT TO ANAL ORIGIN	SNOUT TO VENTRAL BASE	FIRST ANAL RAY TO CAUDAL BASE	LAST ANAL RAY TO CAUDAL BASE	LAST DORSAL RAY TO CAUDAL BASE
A. atlanticus, juv	—	44.5–46.2 or 43.6–45.5	—	54.5 or 55.5	—	—
A. atlanticus, juv	*ca.* 47.8	43.6	*ca.* 35.2–36.6	52.0–53.5	*ca.* 18.3	*ca.* 42.2
A. atlanticus eastern Atlantic	49.0	55.0	43.6	—	—	—
A. atlanticus western Atlantic	46.3–49.0[3]	46.3–47.2 to *ca.* 52.7	*ca.* 39.6–43.1	48.6 to 52.5–53.5	*ca.* 16.4–18.7	39.4 to 43.2–44.0
A. ephippiatus (72) Hawaii	—	—	—	—	—	—
A. ephippiatus, type Hawaii	41.4	54.5	46.0	48.6	17.3	*ca.* 43.4
A. ephippiatus (80) Hawaii	45.0	55.6	44.4	48.7	14.4	*ca.* 41.8
A. iridescens Australia	—	—	—	—	—	—
Argyripnus sp. Philippines	46.4	*ca.* 55.5	46.4	46.4	15.2	*ca.* 41.5

SPECIMENS	LEAST DEPTH OF CAUDAL PEDUNCLE	DORSAL BASE	ANAL BASE	ADIPOSE BASE	PECTORAL LENGTH	FIRST VAV+AC GROUP TO MIDDLE AC GROUP	MIDDLE AC GROUP TO LAST AC GROUP
A. atlanticus, juv. Hawaii	—	—	—	—	—	—	—
A. atlanticus, juv. Hawaii	7.02–8.45	9.84–11.3	*ca.* 32.3	4.22	18.3–19.7	9.84	9.84–11.3
A. atlanticus eastern Atlantic	11.2	—	—	—	23.2	—	—
A. atlanticus western Atlantic	7.04–9.32	11.9–13.2	30.0–33.9	*ca.* 5.8–10.5	18.9–24.4	3.79 to 5.3–6.0	6.9–9.06[5]
A. ephippiatus (72) Hawaii	—	—	—	—	—	2.78	7.65
A. ephippiatus, type Hawaii	8.65	14.0	*ca.* 31.3	*ca.* 8.0	—	—	8.0
A. ephippiatus (80) Hawaii	9.36	10.85	33.1	10.0	25.0	*ca.* 4.37	*ca.* 8.25
A. iridescens Australia	—	—	—	—	24.3	—	—
Argyripnus sp. Philippines	9.14	12.2	31.5	—[4]	21.9	3.05	7.33

[1] Calculated from measurements given by Maul, 1952: 56.
[2] Calculated from measurements given for a single specimen by McCulloch, 1926: 169.
[3] 42.7 and 43.0–43.9 in 2 specimens 55 and 57 mm. in standard length.
[4] Upper surface of tail damaged, adipose fin lost.
[5] 10.0–10.9 in smallest specimen (55 mm.).

mens and may have more gill rakers, although information on the total number of rakers on the first arch of this species is lacking. The single specimen of *Argyripnus* from the Philippines is unique in a few characters. Because of these unique features and because it is the only specimen to have been caught between Hawaii and Australia, the specimen is not identified to species at the present time, although it was originally labeled "*Argyripnus iridescens*" and is catalogued under that name in the collection of the U. S. National Museum.

A few minor errors appeared in the original description of *A. ephippiatus* (Gilbert and Cramer, 1896: 414) and may be corrected as follows: dorsal rays 11 (not 10); BR (6) (not 5); AC in the most posterior group (15) on the left side and (14) on the right side; adipose fin present and undamaged.

The smallest of the 3 specimens of *A. ephippiatus* examined is bent and cannot be measured accurately. The photophores of this specimen and of the holotype are intact, but many of those of the largest specimen are lost (abdomen and ventral portion of tail damaged). In all 3 specimens the tail is a little shorter than the trunk; the anal origin is below the end of the dorsal fin; there is a distinct gap, filled with membrane, between the two groups of anal rays in the holotype and the smallest specimen; the unbroken pectoral fin of the largest fish extends to a point half-way between the ventral and the anal fins. The pseudobranchiae are well developed; on the inner edge of the first gill arch is a series of groups of minute spines and 1 or 2 slightly enlarged spines on the upper limb near the angle. The maxillary reaches the posterior margin of the orbit; 1 or 2 very small teeth are present on each side of the vomer; and on each palatine, anteriorly, are a few still smaller teeth. *A. ephippiatus* differs from *A. atlanticus* in having fewer gill rakers and fewer photophores in the ventral series. It is unique in its lower pectoral count and in having 1 or 2 slightly enlarged spines on the inner edge of the upper limb of the first gill arch.

The specimen from the Philippines has the tail a little shorter than the trunk; the anal origin is below the end of the dorsal fin; there is a short gap between the two groups of anal rays, situated below the third organ of the middle AC group of 5; the pectoral fin extends slightly beyond the ventral base; the back is damaged and the adipose fin is lost. The pseudo-

KEY TO SPECIES OF *Argyripnus*

1a. Anal origin below first few dorsal rays, or slightly anterior to dorsal origin. Gill rakers on first arch 17–19 + 5–7 = 22–26. VAV + AC (24–28) + (5) + (16–18) = 46–51. IC 62–67 ..... *A. atlanticus* Maul
North Atlantic, Hawaii

1b. Anal origin below posterior half of dorsal fin. Gill rakers on first arch 12–16 + 4–6 = 16–19 (20 + ?).[2] VAV + AC (18–21) + (5) + (12–15) = 35–40. IC 51–56.

2a. Gill rakers on lower limb of first arch 13–16. First group of VAV + AC (19–21). IC 53–56. Head 2.6 to *ca.* 3.8 times in standard length.

3a. Pectoral rays 16–17. Depth 3.1–3.4 times in standard length. Orbit 2.5–2.7 times in head length..... *A. iridescens* McCulloch
Australia

3b. Pectoral rays 15. Depth 3.8–3.9 times in standard length. Orbit 1.9–2.25 times in head length..... *A. ephippiatus* Gilbert and Cramer
Hawaii

2b. Gill rakers on lower limb of first arch 12. First group of VAV + AC (18). IC 51. Head 3.85 times in standard length (depth 3.8 times in standard length. Orbit 2.7–2.75 times in head length)..... *Argyripnus* sp.
Philippines

[2] *A. iridescens* with 16 on lower limb; number on upper limb, and total count, unknown.

branchiae are well developed; on the inner edge of the first gill arch is a series of minute spine-clusters but no enlarged spines are present. The maxillary extends to the posterior margin of the orbit; 1 tooth is present on each side of the vomer; 1 minute tooth can be seen anteriorly on each palatine. This specimen differs from *A. atlanticus* in the same characters that distinguish *A. ephippiatus* from that species. It is unique in its low gill raker and photophore counts and its relatively large head.

A description of the western Atlantic specimens of *A. atlanticus* is being published elsewhere.

REMARKS ON MAUROLICID GENERA

The discovery of 2 young specimens of *Argyripnus* and of a new maurolicid genus requires a partial revision of my key to gonostomatid genera published in 1960. Until relationships within the family are better understood, a number of monotypic genera are maintained, however reluctantly, although some of them may prove to be synonymous. For example, *Thorophos, Neophos,* and *Araiophos* may represent 3 species of a single variable genus, but until the characters separating them can be shown to be of specific rather than of generic value it seems advisable to place them in separate genera. Larger series of specimens, the discovery of post-larval stages, and possibly an understanding of their ecology should one day provide the basis for a more definitive classification. In the meanwhile *Neophos* remains separate from *Thorophos* principally on the basis of the biserial premaxillary teeth; the only other genera in the family with 2 rows of teeth on the premaxillary bones are *Yarrella, Triplophos,* and *Polymetme. Neophos* also differs from most maurolicids in having a body form similar to that of several nonmaurolicid genera; only *Araiophos,* among maurolicids, is similarly slender-bodied anteriorly and thus atypical of the group with which it is classified. *Araiophos* is unique in the form and arrangement of the IV photophores, which consist of 2 minute grouped organs on the isthmus, and on the abdomen four large, well-separated organs preceded by a group of 3 tiny photophores and followed by a group of 2 small ones. The abdominal IV show no such differentiation in any other genus in the family.

The 2 genera *Sonoda* and *Argyripnus* may also prove to be synonymous. *Sonoda paucilampa* Grey (1961), a species found recently in the western Atlantic, is in some respects intermediate between the 2 genera; and the discovery at Hawaii of an *Argyripnus* with the anal origin anterior to the dorsal origin, as it is in *Sonoda,* further narrows the gap between the 2 genera.

Material used in the preparation of the following key, in addition to that reported here and in 1960, included a single damaged specimen of *Thorophos euryops* Bruun from "Dana" sta. 3736-v, 9° 17′ N., 123° 58′ E., 28 June 1929, 1000 m. of wire out; and 6 specimens of *Neophos nexilis* Myers, USNM no. 151400, from off Mindanao, Philippines, "Albatross" sta. 5516, 8° 46′ N., 123° 32′ 30″ E., 9 August 1909, 175 fathoms (320 m.).

KEY TO MAUROLICID GENERA OF GONOSTOMATIDAE

1a. AC composed mostly of separate photophores, more or less evenly spaced, usually one or two groups of 2–4 small organs included (always at least 3 separate organs).

2a. Anal origin in advance of dorsal origin. Ventral bases well ahead of dorsal origin. IV on isthmus straight, none curving upward posteriorly. Total number of AC 7–15. IC 22–37. Dorsal rays 8–14. Anal rays 28–38. Gill rakers on first arch 13–15 + 3–5 = 18–19, 2 in angle.

3a. Maxillary reaching to or beyond posterior margin of eye. Anus closer to anal fin than to ventral bases. Dorsal rays 8–11. Anal rays 31–38. OP 3. SO present. Number of IV on isthmus 6, IV present below pectoral base, total number of IV 17. AC present above the most anterior anal rays, total number 13–15. IC 35–37. OA present. (AC mostly single.)

4a. Premaxillary teeth biserial. Lower jaw teeth biserial in anterior half. Dorsal origin about in middle of body length. No adipose fin. Dorsal rays 8–9. Anal rays 38. IV on isthmus 1 + (2) + (3) = 6. VAV 1 + (3) + 1 = 5. OA 1 ..... *Neophos* Myers

4b. Premaxillary teeth uniserial. Lower jaw teeth uniserial?[3] Dorsal origin slightly behind middle of body length. Adipose fin present. Dorsal rays 11. Anal rays 31. IV on isthmus 3 + (3) = 6. VAV (5). OA (2) + 5 = 7..... ..... *Thorophos* Bruun

3b. Maxillary reaching slightly past middle of eye. Anus half-way between ventral bases and anal origin or slightly nearer ventral bases. Dorsal rays 13–14. Anal rays 28–29. OP 1. SO absent. Number of IV on isthmus (2), no IV below pectoral base, total number of IV 11. AC absent above the most anterior anal rays, total number 7–8. IC 22–23. No OA. (Dorsal origin well behind middle of body length. Adipose fin present.) ..... ***Araiophos,*** new genus

2b. Anal origin behind or below last dorsal ray. Ventral bases below dorsal fin. IV on isthmus curving upward posteriorly. Total number of AC 22–26. IC 45–49. Dorsal rays 6. Anal rays 24–25. Gill rakers on first arch 10–12 + 1 + 2 = 13–15, only 1 in angle. (Dorsal origin well in advance of middle of body length. Anus about half-way between ventral bases and anal fin or slightly nearer anal. Adipose fin present or absent. SO absent. Total number of IV 18, (3) + (4) on isthmus. AC present above the most anterior anal rays. Vertebrae 38.) ..... *Danaphos* Bruun

1b. AC composed of 2 to 5 groups of 2 or more photophores each (1 separate organ present anteriorly only in *Maurolicus*). (Two gill rakers in angle of first arch.)

5a. AC in 3 to 6 groups of 2 to 4 small photophores each. IV (3) + (4) on isthmus, (16–17) on abdomen, total 23–24. VAV (4–5). Gill rakers on first arch 12 + 2–3 = 14–15. (Anal origin below or slightly in advance of dorsal origin. Adipose fin present. Anus closer to anal origin than ventral bases. No SO. No AC above the most anterior anal rays. Vertebrae 32–33?.) ..... *Valenciennellus* Jordan and Evermann

5b. AC in 2 or 3 groups of 5 or more photophores each. IV (6, rarely 7) on isthmus, (10–13) on abdomen, total 16–19. VAV (6–8), *or* joined to anterior group of AC (*Argyripnus*). Gill rakers on first arch 12–22 + 3–8 = 16–30.

6a. Anus about half-way between ventral bases and anal fin or nearer ventrals. Dorsal origin about in middle of body length. SO absent. Lower posterior OP greatly enlarged. IV (6, rarely 7) + (10, rarely 9 or 11) = 16 (rarely 15 or 17). Total number of OA 6–7.

7a. No adipose fin. VAV (7–8), well separated from AC. AC in 2 long groups or 3 short groups, absent above the most anterior anal rays. Dorsal rays 8–9. (Vertebrae 40 and ?.) ..... *Sonoda* Grey

7b. Adipose fin well developed. VAV grouped with photophores above the most anterior anal rays, this group numbering (18–28) in adult. Dorsal rays 10–14. (Vertebrae 47 and ?.) ..... *Argyripnus* Gilbert and Cramer

6b. Anus near anal fin. Dorsal origin well behind middle of body length. SO present. Lower posterior OP of normal size. IV (6) + (12–13) = 18–19. Total number of OA 9 (rarely 10). (Adipose fin present. AC present above the most anterior anal rays, in 2 groups of (14–18) and (7–9) photophores, preceded by a single elevated organ. Vertebrae 32–33.) ..... *Maurolicus* Cocco

[3] Premaxillary and lower jaw bones lost from only specimen of *Thorophos* examined.

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Amorphous Mineral Colloids of Soils of the Pacific Region and Adjacent Areas[1]

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THE PRESENCE of amorphous mineral colloids in soils and geologic formations is not as uncommon as was first believed in the early years following the acceptance of the clay mineral concept. In the early reports the occurrence of amorphous material was associated with only a few rare and isolated clay materials. Because amorphous colloids are not the major component in most soils and their presence may be found in relatively low concentrations, if found at all, their detection has been difficult. Moreover, whereas crystalline clay minerals are relatively uniform in composition, the amorphous materials exhibit a varying degree of composition and poor degree of crystallinity, further adding to the difficulty in their identification. Often their presence has been suggested only because mineral allocations of crystalline materials failed to add up to 100 per cent. In recent years improvement in the use of techniques such as X-ray diffraction, infrared absorption, electron microscopy, and surface area determination, has made it possible to make significant progress in the study of amorphous colloids.

Much of the research dealing with amorphous mineral colloids in soils has been conducted by soil scientists working in the Pacific region or in its adjacent areas. The leadership in this field definitely belongs to this group of researchers. It is the object of this paper to review and discuss the contributions of these workers in order to obtain a better perspective of this very important fraction of soils. These investigators have pointed out that the amorphous constituents make up a sizeable fraction in many soils occurring in Hawaii, Japan, New Zealand, Oregon, and other Pacific areas. These amorphous mineral colloids play a prominent role in soil formation and also impart certain distinctive and unique properties to the soil. Thus, a review of this nature appears justified.

NOMENCLATURE OF AMORPHOUS COLLOIDS

The isolation and description of amorphous colloids have been difficult because of the great variability in materials. Moreover, early samples classified as "amorphous" were actually found to be finely crystalline with modern X-ray diffraction methods. Stromeyer and Hausmann first used the name allophane to describe amorphous material lining cavities in marl in 1816. Since that time many related materials have been called allophane and this term has become associated with amorphous constituents of clay. Ross and Kerr (1934) described allophane as essentially an amorphous solid solution of silica, alumina, and water having no definite atomic structure, and they applied the term allophane to a great number of amorphous clay materials regardless of their composition. They studied five specimens of allophane, all essentially hydrous aluminum silicates, and found that SiO_2 ranged from 25 to 34 per cent, Al_2O_3 from 30 to 36 per cent, and H_2O from 31 to 38 per cent. The New Zealand workers (Fieldes *et al.*, 1952, 1954; Birrell and Gradwell, 1956) have used the term amorphous colloidal hydrous oxides apart from the term allophane in their description of amorphous clays. With allophane, which is considered to be one of the most important amorphous minerals, Fieldes (1955, 1956) has preferred to recognize three distinct

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forms: allophane A, allophane B, and the intermediate form, allophane AB. In classifying the clay minerals Grim (1953) has included only the allophane group under the amorphous clay minerals. Brown (1955) in his proposed nomenclature has divided the amorphous minerals into oxides, silicates, and phosphates. In this system, allophane is included in the silicates.

OCCURRENCE OF AMORPHOUS COLLOIDS

Kelley and Page (1943) in their mineralogical investigation encountered two soils from Naalehu and South Point on the island of Hawaii that exhibited very high cation exchange capacities, 120 m.e. and 88 m.e. per 100 g., respectively. They reported that differential thermal analysis showed pronounced endothermic peaks at 160° C. for these two soils in addition to showing weak X-ray diffraction patterns. These investigators, therefore, concluded that the high cation exchange properties were related to the presence of considerable amorphous material. Included in this study were soils from Vale, Oregon, and the Mojave Desert, which also gave very indistinct X-ray lines and showed low temperature breaks, inferring the presence of amorphous material.

Dean (1947) in his D.T.A. study of a number of Hawaiian soils derived from ash and lava found that many of these soils contained almost no crystalline clay minerals. In addition some showed almost no hydrous oxides. It was previously shown by Ayres (1943) that some of these same soils possess very high inorganic cation exchange capacities. Dean concluded that it was possible that some of these soils contain alterations of the kaolin minerals.

Tanada (1950) divided Hawaiian soils into five groups on the basis of chemical analyses and dehydration studies. He obtained similar high cation exchange capacity values for the two soils, Naalehu and South Point, that Kelley and Page (1943) had previously reported. However, Tanada did not draw any conclusions regarding the cause of such high values.

Tamura, Jackson, and Sherman (1953) employed X-ray, chemical, thermal, and infrared techniques and found up to 30 per cent allophane in the less than 0.2 micron fraction of two hydrol humic latosols from the island of Hawaii. The authors noted that the allophane found in the subsoil of one of these soils was very similar to allophane from Woolwich, England (Kerr, 1951). Gibbsite and goethite were reported to make up the bulk of the remaining clay fraction. They also investigated the low humic latosols and reported that the dominant minerals are of the kaolin family. Up to 10 per cent allophane was found to occur in the clay fraction of this group of soils.

In a subsequent paper (1955) the same authors reported on a humic ferruginous latosol from the island of Maui which showed that almost 30 per cent of the clay fraction in the subsoil was composed of allophane.

The occurrence of allophane in some soils of northwestern Oregon was suggested by Whittig *et al.* (1957). These soils, members of the Cascade and Powell series, contained relatively high percentages of alkali-soluble silica and alumina. The amorphous alumino-silicate in these soils was formed by weathering of aeolian volcanic ash.

In earlier work, Whittig (1954) reported the occurrence of a more stable form of allophane in two humic ferruginous latosols of Hawaii. The allophane of these soils had a relatively low cation exchange capacity (of the order of 10 m.e. per 100 g.) and resisted solution in boiling Na_2CO_3 solution.

More recently Bates (1961) described the presence of mineral gels in Hawaiian soils which are mixtures of aluminum, iron, silica, and titanium compounds. The gel material is very reactive chemically and gives rise to inorganic and organomineral complexes in the colloid fraction.

Matsusaka and Sherman (1960) have reported that the iron hydroxide and oxide of the amorphous mineral colloid fraction of Hawaiian lateritic soils will form strongly magnetic iron oxides on dehydration. This may help explain the magnetic properties of weathered ferruginous geological formations.

In Japan Sudo (1954), Sudo and Ossaka (1952), and Aomine and Yoshinaga (1955) have pointed to allophane as the dominant constituent of Ando soils which are formed from volcanic ash. These soils are characterized by a

low bulk density, a high organic carbon content, and low base saturation. These properties are attributed to the preponderance of allophane. The Ando soils and related types are found associated with the Pacific ring of volcanic activity. These Japanese workers have found that the fine clay fraction of the Ando soils is characterized by being amorphous to X-rays and possesses medium-to-high cation exchange capacities and high phosphate- and ethylene glycol-retention values.

The New Zealanders have also worked extensively on the identification of amorphous constituents. In 1952 Birrell and Fieldes (1952) and Birrell (1952) identified the presence of amorphous material, principally allophane, in soils derived from rhyolitic and andesitic ash. The allophane was found to be present mainly in the clay fraction although it was inferred that it was present to some extent in the silt fraction. These soils were characterized by a high water-holding capacity, high shrinkage, and irreversible drying, characteristics that are strikingly common to many other Pacific region soils dominated by allophane. Birrell (1952) also pointed out that these soils had a waxy appearance and were greasy to the feel, yet they were not unusually sticky. He further noted that associated with nonreversible drying, liquid and plastic limit values were much greater for undried soils than for dried soils.

Later reports, especially by Fieldes and his co-workers (1955, 1956, 1957, 1955), have confirmed that allophane and other amorphous constituents dominate many New Zealand soils derived from volcanic ash and, in some cases, basaltic parent materials. These workers utilized electron microscopy, differential thermal analysis, and infrared absorption extensively in identifying the presence of amorphous constituents.

PEDOGENIC SIGNIFICANCE OF AMORPHOUS COLLOIDS

Ross and Kerr (1934) described allophane as an amorphous hydrous aluminosilicate having no definite chemical composition and that it is commonly associated with halloysite. They were careful to point out that it is not a microscopic mixture of amorphous silica and alumina. Kerr (1951) offered confirmatory evidence by absorption spectra that allophane is not a mixture of alumina and silica.

Tamura *et al.* (1953) assigned allophane to weathering stage 11 or the gibbsite stage in the weathering sequence of clay-size minerals as presented by Jackson *et al.* (1948). They noted that the trend for increased gibbsite with increased rainfall is very marked in passing from the low humic latosols to the hydrol humic latosols. With this increase in gibbsite is an associated increase in allophane.

A mechanism for the transition of alumina and silica through allophane to kaolin was proposed by Tamura and Jackson (1953). The steps are as follows: (1) amorphous hydrous alumina crystallizes to a gibbsite structure; (2) with partial dehydration, hydroxyls in the gibbsite octahedra are replaced by oxygens of the silica tetrahedra; (3) this process occurs in the presence of silica solutions and continues through entrance of silica between gibbsite sheets, resulting in a cross-linking of silicated octahedral sheets of alumina which corresponds to allophane; (4) kaolinite is formed from allophane on completion of unidirectional bonding through alternate wetting and drying in an acid medium where enough silica is available.

The stable, nonreactive form of allophane reported by Whittig (1954) as a constituent of some humic ferruginous latosols of Hawaii was considered to be a weathering product of halloysite. Electron micrographs of clay fractions of these soils revealed a transition from well-developed halloysite rod structures to spherical, X-amorphous allophane particles. It was suggested that partial removal of silica from the rigid halloysite rods by leaching allowed the rods to curl up in a direction perpendicular to their original curvation. Allophane formed in this way possessed properties quite different from those of the more labile allophane described by Tamura and Jackson (1953) and would occupy a lower position in the weathering sequence of Jackson *et al.* (1948).

More recently Bates (1960) suggested that the development of allophane is a logical stage in the weathering of certain Hawaiian volcanic ash and also in the matrix of rock. In other cases, he indicated that allophane is an inter-

mediate stage in the weathering sequence of halloysite to gibbsite. Bates also reported the formation of gibbsite crystals upon dehydration of amorphous Fe-Al gels. This observation supports Sherman (1957), who reported that crystalline gibbsite aggregates formed when the soils of the Hydrol Humic Latosol group were air dried. These soils have a high content of amorphous mineral colloids which contain a substantial amount of gel material.

Some of the Japanese workers (Sudo, 1954; Sudo and Ossaka, 1952) conclude that allophane precedes halloysite in the weathering sequence from ash to allophane to halloysite. Aomine and Yoshinaga (1955) have also emphasized that the clay fraction of the volcanic ash soils of Kyushu and Hokkaido formed under similar well-drained conditions is predominantly allophane, regardless of differences in temperature, weathering time, vegetation, and ash origin.

The New Zealanders have also tried to properly position the amorphous materials in the weathering sequence. Fieldes and Swindale (1954) have prepared a flow sheet tracing the mechanism of silicate minerals weathering. They have proposed that the nature of the clay constituents of any soil can be predicted if its parent material and weathering stage are known. The amorphous materials occupy a great role in this flow sheet in that it is thought that the primary silicates (aside from the micas) cannot form layer silicates without first passing through an amorphous stage. Clays derived from rhyolitic and andesitic ash pass through the weathering sequence from amorphous hydrous oxides through allophane to meta-halloysite and kaolin. It is believed that many of the Hawaiian soils derived from andesitic ash follow this same sequence.

In an earlier paper Fieldes *et al.* (1952) emphasized that the amorphous hydrous oxides played more than a brief transitory role. They reported some soils of the lower Cook Islands which showed high cation exchange capacity values. These soils were all low in silica, and also allophane was not found to be a constituent in them. They attributed the cation exchange capacity mainly to the amorphous hydrous oxides.

In later papers Fieldes (1955, 1956, 1957) reported enough fundamental differences in allophane to warrant recognizing three types: allophane A, allophane B, and the intermediate type, allophane AB. Based mainly on infrared absorption data, it was found that silica is linked with alumina to form allophane A while some silica is discrete as amorphous hydrous silica in allophane B. Fieldes could offer no satisfactory explanation as to why co-precipitation and linking of alumina and silica occur to only a limited extent in allophane B. He did not want to state that allophane B is simply a mixture of amorphous alumina and silica. Differential thermal analysis shows that a high temperature exotherm between 850° and 1000° C. is strong in allophane A, not present in allophane B, and weakly developed in the intermediate form, allophane AB. Fieldes (1955) has presented a weathering sequence of clays derived from rhyolitic and andesitic ash: allophane B—allophane AB—allophane A—meta-halloysite—kaolinite. He has stated that in this sequence the stable form is meta-halloysite and progress towards this stable form through allophane A is consistent with the mechanism proposed by Tamura and Jackson (1953). The structure consisting of hydrous alumina octahedra randomly cross-linked by silica tetrahedra and called allophane by Tamura and Jackson would hence correspond to allophane A as proposed by Fieldes.

There is a growing consensus among investigators in this field that amorphous colloids may play a very important role in soil formation and in establishing properties of many soils of the continental United States as well as in the Pacific islands. Because of their noncrystalline nature, identification of allophane and other amorphous constituents is at present very difficult, and at best very unreliable, by standard methods of analysis unless they be present as predominant components of their system. In view of the fact that transition from primary silicates (with the exception of micas) to the secondary layer silicates must include some solution and reprecipitation, it is reasonable to suspect that amorphous colloids exist, at least as a transition stage, in most of our soils. The extent of their presence is masked in most of our mineralogical studies by the crystalline components present.

The fact that amorphous colloids greatly affect properties of soils where they are dominant constituents emphasizes the need for more critical examination of our soils for evidence of their presence. According to Kanehiro and Sherman (1956), it is well established that allophane has low bulk density, high water-holding capacity, and, in some cases at least, a high cation exchange capacity. In addition it has been observed that allophane has a strong aggregation effect on soils, a very high phosphate fixing capacity, and the ability in some cases to fix organic compounds so as to render nitrogen available with difficulty to microorganisms and higher plants (T. Sudo, private communication).

Early researches of Burgess and McGeorge (1926) and Burgess (1929) in Arizona suggested that amorphous alumina, silica, or aluminosilicate may be formed quite readily in soils by application of alkaline solutions. Kerr (1928) further postulated that amorphous aluminosilicates may form even in slightly acid soils as a result of local hydrolysis of feldspars, solution of alkaline silicates and aluminates, and subsequent co-precipitation.

The Pacific region and its adjacent areas, with their recent volcanic materials offer a splendid opportunity for investigation of the presence of, the properties imparted by, and the mechanisms of formation of, such amorphous constituents in soils.

SUMMARY

The work on the amorphous mineral colloids of soils of the Pacific region and its nearby areas is described.

The amorphous colloids, especially allophane, dominate the clay fraction of many soils derived from volcanic ash, as well as some rocks, in the Pacific area. Soils dominated by these amorphous colloids have many distinct and unique properties. The position of the amorphous colloids, especially of allophane, in the weathering sequence remains to be fully clarified.

For many reasons, the identification of amorphous colloids is often difficult; however, recent improvements in instrumental techniques have greatly facilitated this identification.

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NOTE

Daylight Surface Occurrence of Myctophid Fishes Off the Coast of Central America

FRANKLIN G. ALVERSON[1]

THE CAPTURE off the coast of Central America of *Benthosema pterota* (Alcock, 1891), by California-based tuna clippers, on three known occasions, at the surface during daylight hours is worthy of note. Myctophids are ordinarily believed to be bathypelagic in nature and associated with the twilight zone of the sea. The fact that myctophids make nocturnal migrations to the surface has long been known and many specimens have been taken at the surface during the hours of darkness.

The first daylight capture of *Benthosema pterota* was recorded 13 mi. west of Cape Blanco, Costa Rica, on March 14, 1952, by the tuna clipper "Anna M." The fish were taken with a dip net at 1300 on a clear day from the fishing racks of the vessel. The water was clear and the surface temperature was 82.5°F. The skipper, Ted Sorensen, reported three "balls" of reddish-brown bait at the surface with yellowfin tuna (*Neothunnus macropterus*) feeding voraciously on them. The fish, as described by Sorensen, were in tight elliptical aggregations measuring about 10 ft. in length and 3 ft. in depth. The tuna feeding upon the myctophids refused the fish (*Cetengraulis mysticetus*) used by this vessel for live bait when it was offered to them.

A second capture of the species at the surface during daylight hours was reported by a crew member of the tuna clipper "Sun Traveler"; the capture was made on March 15–20, 1954, 65 mi. southwest of Caño Island, Costa Rica. Mr. Joseph Silva observed the fish at 10:00. They also appeared as a reddish-brown "ball" being fed on by skipjack (*Katsuwonus pelamis*), yellowfin tuna, and sea birds. Four other small schools were seen in the same locality. The clipper left the immediate area at this time and returned at 16:00 the same day. At this time, the schools of myctophids were still on the surface and when the vessel drew close they took shelter under the stern, evidently for protection from the yellowfin and skipjack. Specimens were easily captured with a dip net from the racks on the stern of the vessel.

A third occurrence of this species on the surface during daylight hours was noted on April 7, 1955, at 13° 19′ N. and 91° 16′ W. by the crew of the tuna clipper "Commadore." The fish were again captured with a dip net from the stern of the vessel while it was fishing for yellowfin. The fish again appeared as reddish-brown "balls" on the surface.

The table below gives the size range and mean standard length for the three samples of *Benthosema.*

Although only three samples have been obtained by the author, apparently the sighting by fishermen of myctophid schools on the surface during daylight hours in the spring of the year is not uncommon. Mr. Edward Silva, managing owner of the "Santa Rosa," says that fish fitting the description of myctophids have been taken by clippers and attempts made to use them as tuna bait. However, the fish scaled easily, were weak, and were unsatisfactory for bait. Mr. Manuel Luz, former skipper of the "Saratoga," said he has seen many small "balls" of bait in the waters off Costa Rica during the spring of the year that fitted the same description. He also noted that the fish made poor bait because they scaled easily and were too weak for retention in the bait wells.

[1] Inter-American Tropical Tuna Commission, La Jolla, California.

NO.	DATE OF CAPTURE	NO. MEASURED	MEAN STANDARD LENGTH (mm.)	RANGE IN STANDARD LENGTH (mm.)
1	March 14, 1952	49	39.0	35–47
2	March 15–20, 1954	43	46.3	38–54
3	April 7, 1955	50	35.2	32–40

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Notes on Larvae, Juveniles, and Spawning of Bonito (*Sarda*) from the Eastern Pacific Ocean

W. L. KLAWE[1]

TWO SPECIES OF BONITO occur along the Pacific coast of the Americas (Hildebrand, 1946).[2] *Sarda chiliensis* ranges from southern British Columbia to northern Chile; the other species, *S. orientalis,* is found from Baja California to the Galapagos Islands and northern Peru. These species are of considerable importance to both commercial and sport fisheries of certain countries (Walford, 1937; Berdegué, 1956). The bonito fishery in Peru, especially for *S. chiliensis,* is particularly important. It contributes significantly to the economy, being valuable to the domestic market as well as for export. The following table gives the commercial catches of bonito, expressed in thousands of metric tons, during the past few years:

	OFF PERU	OFF CALIF.	WORLD TOTAL
1950	31.8	0.3	61.6
1951	51.2	0.4	76.9
1952	50.3	1.0	76.1
1953	44.4	1.4	83.8
1954	52.8	1.1	114.4
1955	71.8	0.1	173.1
1956	83.4	0.1	189.9
1957	58.6	0.1	145.5
1958	66.2	2.4	163.5

Despite the commercial importance of bonitos, knowledge of their biology is relatively meager. Little is known of the early life history and spawning, and descriptions of the eggs, larvae, and juveniles of *Sarda* are limited to a few reports. The only descriptions of young bonitos from the eastern Pacific Ocean are those of *S. chiliensis* by Barnhart (1927) and Orton (1953*a*, 1953*b*). Descriptions of eggs and young from other parts of the world seas are limited to the reports listed in Table 1.

The information on spawning of bonito is scant. According to Vildoso (1955), *S. chiliensis* reproduces in Peruvian coastal waters from October to March with the peak of spawning occurring from December to February. From Barnhart's work (1927) it is evident that off La Jolla, California, *S. chiliensis* spawns in June. Walford (1937) stated that in the northern latitudes this species spawns during the late spring and summer close to shore to as far out as 80 mi. Observations on spawning bonito in other parts of the world are limited to the reports on *S. sarda* tabulated below:

AREA	SPAWNING TIME	REFERENCE
Mediterranean..	May–Jun.	Sanzo, 1932
Black Sea.....	Apr.–Aug.	Borcea, 1939, 1933
		Vodyanitsky, 1936
		Malyatsky, 1940
		Numan, 1955
Atlantic,		
off Morocco..	Jun.–Jul.	Furnestin *et al.,* 1958
off Dakar.....	Feb.–Mar.	Frade and Postel, 1955
U.S. coast.....	Jul.	Sette, 1943
	Jun.	Bigelow and Schroeder, 1953

During the course of collecting biological material and other scientific data from commercial fishing vessels and research ships operating in waters of the eastern Pacific Ocean, staff members of the South Pacific Fishery Investigations of the U. S. Bureau of Commercial Fisheries, Scripps Institution of Oceanography, and the Inter-American Tropical Tuna Commission have captured a variety of larval and juvenile fish, including young of *Sarda.* The data on the collections of young bonito made by these organizations with some other records, kindly put

[1] Inter-American Tropical Tuna Commission, La Jolla, California. Manuscript received September 26, 1960.

[2] It is assumed that *S. lineolata* (Girard)=*S. chiliensis* (Cuvier and Valenciennes) and that *S. velox* Meek and Hildebrand=*S. orientalis* (Temminck and Schlegel). *S. chiliensis* and *S. sarda* from the Atlantic Ocean and adjacent seas may be synonymous. A detailed discussion on the relationship of the species of the genus *Sarda* is provided by Godsil (1955).

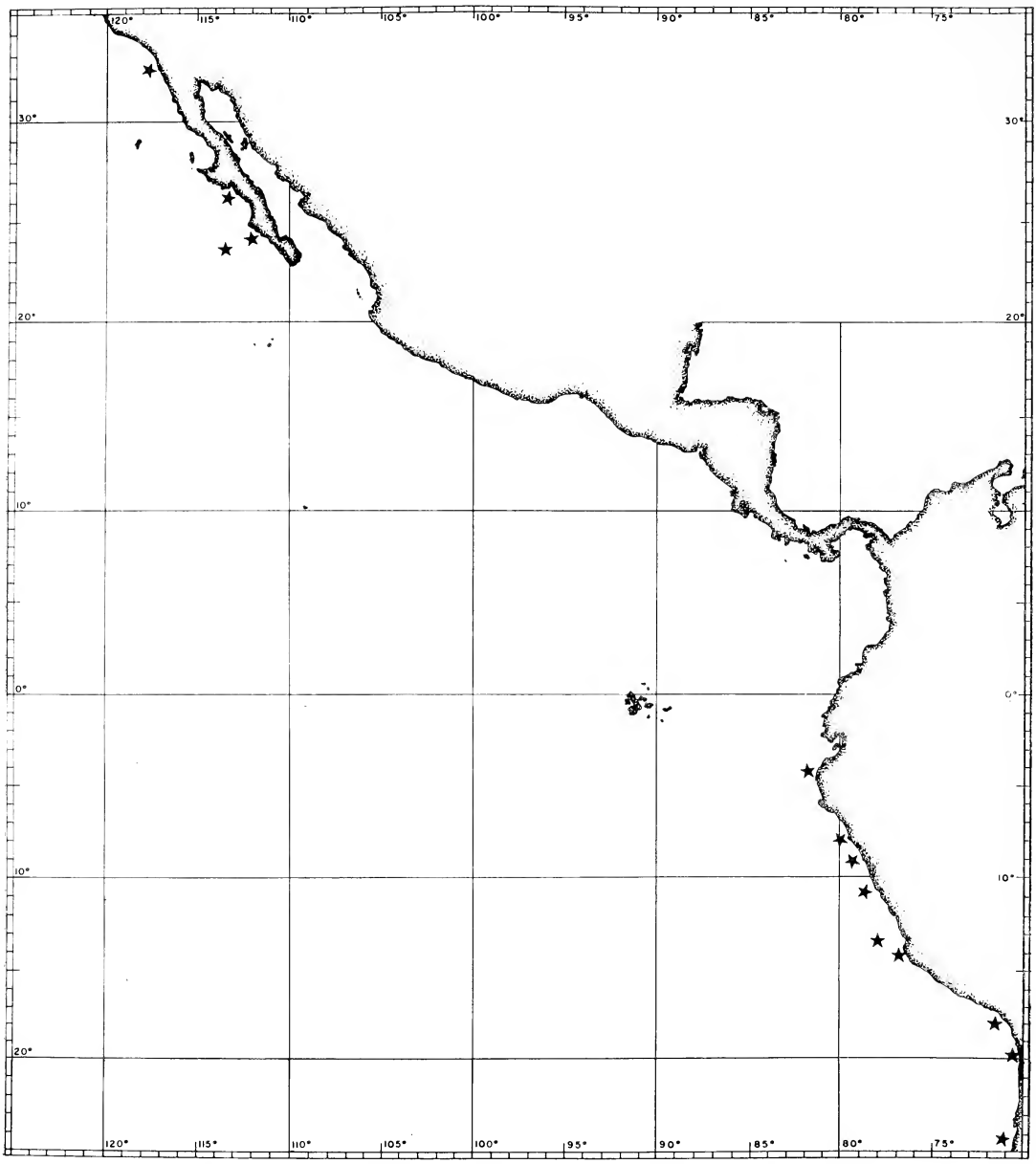

FIG. 1. Localities of capture of young *Sarda* in eastern Pacific Ocean.

at the Commission's disposal, are given in Table 2. The geographical distribution of these catches is shown in Figure 1.

The author wishes to thank Mr. Gerald V. Howard and Dr. Elbert H. Ahlstrom of the U. S. Bureau of Commercial Fisheries for their helpful criticism and suggestions on the preparation of this manuscript. The manuscript upon its completion in 1959 was made available to Mr. Leo Pinkas of the California Department of Fish and Game. Thanks are extended to Sra. Aurora Chirinos de Vildoso of the Peruvian Pesca y Caza for her cooperation in exchange of various data.

TABLE 1

SPECIES	MONTH COLLECTED	PLACE	SIZE OR STAGE	REFERENCE
S. sarda	Jun.	Mediterranean	7.2 mm.	Ehrenbaum, 1924
S. sarda	Jul.	Mediterranean	26.5, 32 mm.*	de Buen, 1930
S. sarda	Jun.	Mediterranean	eggs and early larvae	Sanzo, 1932
S. sarda	Jun.	Black Sea	eggs and early larvae	Vodyanitsky, 1936
S. sarda	Mar.	Gulf of Mexico	64, 67 mm.	Klawe and Shimada, 1959
S. sarda	Feb.	Western Atlantic	34 mm.	Klawe, in press
S. orientalis	Apr.	Japan	170 mm.	Kishinouye, 1923
S. orientalis	Sep.	Japan	230 mm.	Kishinouye, 1923

* The 17.5 mm. individual represented by de Buen (1930) in figure 1 and originally identified by him as *Sarda sarda* has 39 vertebrae and was reidentified by him as *Auxis thazard* (de Buen, 1932).

DESCRIPTION AND IDENTIFICATION OF LARVAE AND JUVENILES

Two larvae of total lengths 2.9 and 3.5 mm. captured in a plankton tow off Baja California (Table 2) have been previously identified as those of *Sarda* by Alhstrom. An illustration of the larger specimen is given in Figure 2. These larvae have the usual characteristics of larval scombroid fishes. When the material was compared with Sanzo's (1932) and Vodyanitsky's (1936) descriptions and illustrations of larvae of *S. sarda* hatched in the laboratory, the similarity was obvious, although their specimens were less advanced in development. Sanzo and Vodyanitsky report that their lavae measured about 4.3 mm. However, Sanzo and Vodyanitsky were working with fresh material, while the planktonic larvae caught off Baja California had been preserved in formalin.

Barnhart's (1927) observations concerning larval bonito are based on material hatched in the laboratory from eggs collected in a plankton net off La Jolla, California. One of the striking differences between his description and that of *S. sarda* by Sanzo and Vodyanitsky and that of *S. chiliensis* by Orton (1953*a*, 1953*b*) is the absence of melanophores in Barnhart's material. Barnhart credits the newly hatched bonito with a few yellow chromatophores; on the other hand, Sanzo and Vodyanitsky show that in addition to the yellow pigment there are melanophores on the eggs just prior to hatching and the larvae are also provided with numerous melanophores. Barnhart based his description upon material which probably had been preserved in Bouin's solution, which has the property of fading melanine according to Orton (1955).

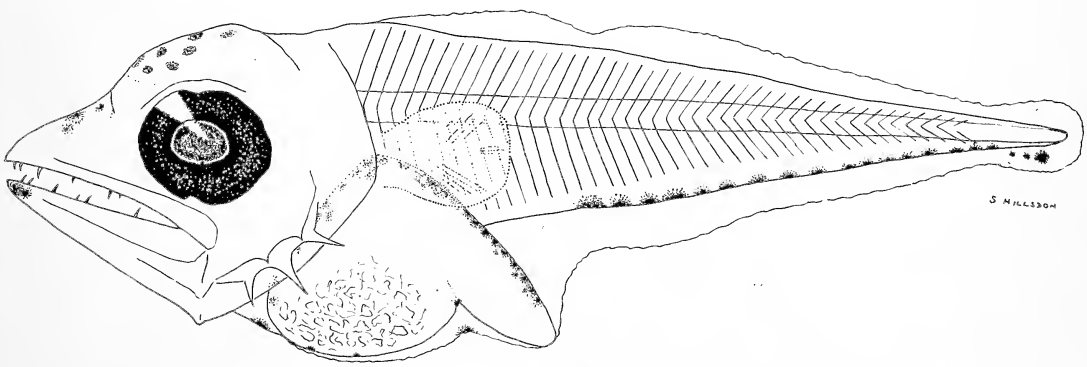

FIG. 2. A 3.5 mm. *Sarda* sp. caught on August 12, 1951, off Baja California.

TABLE 2

RECORDS OF CAPTURE OF DEVELOPING EGGS AND YOUNG *Sarda* FROM THE EASTERN PACIFIC OCEAN

DATE	GENERAL LOCALITY	LATITUDE	LONGITUDE	HOW CAPTURED	SIZE,[1] mm.	NO.	SPECIES	REFERENCE OR COLLECTOR
Jun. 30, 1927	off La Jolla, Calif.			plankton net	eggs	?	*chiliensis*	Barnhart, 1927
May 17–18, 1947	off La Jolla, Calif.			night light, dip net	post-larva	1	*chiliensis*	Hubbs[2]
Feb. 20, 1951	off Pt. Lobos, Peru			?	125–130	3	*chiliensis*	Vildoso, 1955
Aug. 5, 1951	off Baja Calif., Mexico	25° 35′ N.	113° 56′ W.	night light, dip net	42	1	*chiliensis*	Fish & Wildlife Service[3]
Aug. 12, 1951	off Ballenas Bay, Baja Calif., Mexico	26° 29.5′ N.	113° 29.2′ W.	plankton net	2.9, 3.5	2	?	Fish & Wildlife Service[3]
Jan. 3, 1956	off Pt. Negra, Peru			bait net	143–164	3	*chiliensis*	M.V. "Corsair"[4]
Dec. 10, 1957	Independencia Bay, Peru	14° 14′ S.	76° 12′ W.	bait net	128	1	*chiliensis*	B.M. Chatwin & P. Boylan[4]
Dec. 18, 1957	off Ilo, Peru			bait net	70–135	3	*chiliensis*	Arnold Neves[4]
Dec. 31, 1957	off Pt. Pichalo, Chile	19° 35′ S.	70° 16′ W.	night light, dip net	37	1	*chiliensis*	B.M. Chatwin & P. Boylan[4]
Jan. 3, 1958	off Pt. Dos Reyes, Chile	24° 30′ S.	70° 49′ W.	night light, dip net	39	1	*chiliensis*	E. Brinton[5]
Jan. 3, 1958	off Pt. Dos Reyes, Chile	24° 36′ S.	71° 01′ W.	night light, dip net	36–44	3	*chiliensis*	E. Brinton[5]
Jan. 14, 1958	SW off Fraile Pt., Peru	13° 14.8′ S.	77° 55.5′ W.	night light, dip net	34	1	*chiliensis*	E. Brinton[5]
Feb. 1958	off Chimbote, Peru			bait net	89–129	3	*chiliensis*	Arnold Neves[4]
May 6, 1958	Almejas Bay, Baja Calif., Mexico			bait net	103	1	*chiliensis*	M.V. "Lou Jean"[4]
Feb. 1, 1959	Sama Cove, Peru			bait net	111	1	*chiliensis*	M.V. "Normandie"[4]
Mar. 15, 1959	off Ilo, Peru			?	135–160	3	*chiliensis*	P. Talledo[6]
Mar. 16, 1959	off Barranca, Peru			?	173, 199	2	*chiliensis*	Vildoso[6]

[1] Direct distance from tip of snout to tip of shortest median caudal ray.
[2] Field-book data of C. L. Hubbs, Scripps Institution of Oceanography, La Jolla, Calif.
[3] In the collection of the South Pacific Fishery Investigations of the U.S. Fish and Wildlife Service, La Jolla, Calif.
[4] In the collection of the Inter-American Tropical Tuna Commission, La Jolla, Calif.
[5] In the collection of the Scripps Institution of Oceanography, La Jolla, Calif.
[6] In the collection of the laboratory of Pesca y Caza, Lima, Peru.

The planktonic specimens caught off Baja California have between 43 and 45 myomeres, the actual number being difficult to establish. The mouth is large and contains a set of large teeth. There are three spines along the posterior edge of the preoperculum. The unpaired fins show little development and are still represented by the median fin fold. The embryonic pectorals can be distinguished but there is no indication of the pelvics. The pigmentation of the head consists of distinct chromatophores over the area of the brain and an aggregation of what appears to be a group of chromatophores at the symphysis of the pectoral girdle. There

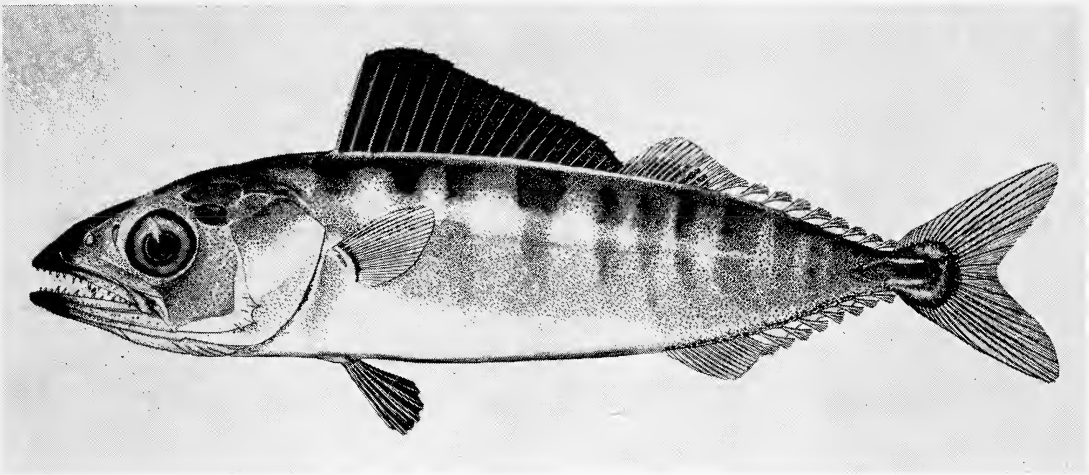

FIG. 3. A 42 mm. *Sarda chiliensis* caught on August 5, 1951, off Baja, California. Drawing by George Mattson of the U. S. Bureau of Commercial Fisheries.

are concentrations of chromatophores in various parts of the peritoneum but especially along its dorsal portion. A series of chromatophores can also be seen along the mid-ventral line extending almost to the tip of the urostyle.

Identification of the two specimens, as to which of the two species they represent (*S. chiliensis* or *S. orientalis*), is impossible without a complete developmental series.

Other specimens of *Sarda* available from the eastern Pacific Ocean are several individuals over 30 mm. in length caught off Chile and Peru and two individuals caught off Baja California. On the basis of gill raker counts (see next paragraph), all individuals have been identified as *S. chiliensis*. A 43 mm. individual caught off Baja California is illustrated in Figure 3. The general appearance of these juveniles resembles that of *Euthynnus* sp. However, separation between these fishes is possible, as the outline of the first dorsal fin is concave in *Euthynnus* and convex in *Sarda* when the spines are erect. Upon closer examination the two genera can be separated easily, as the meristic counts differ considerably. The densely pigmented pelvic fins shown in Figure 3 are characteristic of small *Sarda*. It is worthwhile to mention that the first dorsal fin in small *S.*

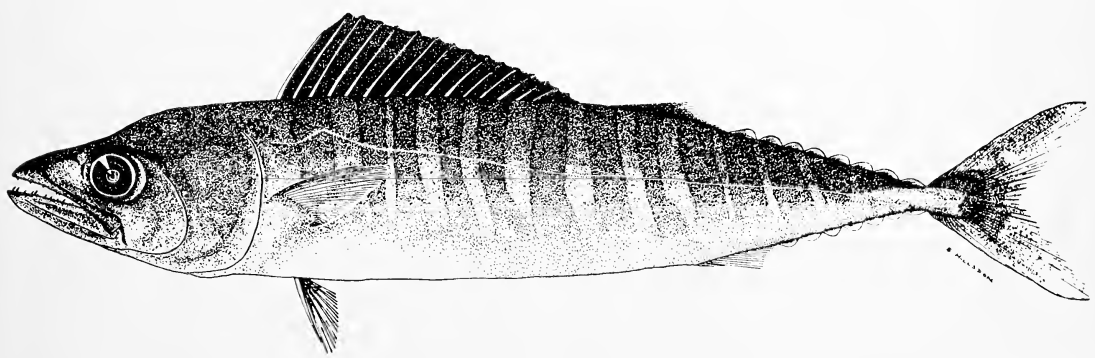

FIG. 4. A 160 mm. *Sarda chiliensis* caught on January 3, 1956, off northern Peru.

chiliensis is either dark with a lighter area in the posterior region of that fin or is uniformly dark. The bodies of all juvenile *S. chiliensis* examined are striped vertically. This also applies to other species of *Sarda* (Kishinouye, 1923; de Buen, 1930; Furnestin *et al.*, 1958; Klawe and Shimada, 1959). A 160 mm. individual of *S. chiliensis* is illustrated in Figure 4. The vertical striations still persist. According to Vildoso (1955), these vertical bars are replaced by oblique markings characteristic of *S. chiliensis* at an approximate length of 320 mm. It should be mentioned that adult *Sarda chiliensis,* when captured, briefly exhibit dusky vertical bands quite like those on preserved juveniles, although not as intense. The body shape of the specimen illustrated in Figure 4 is like that of an adult. The pigmentation of the pelvic fins at this size is confined only to the more basal portion.

As the gill rakers are one of the characteristics used for separating adults of *S. chiliensis* from *S. orientalis,* it is important to establish at what length they develop and at what length the final complement is attained. The gill raker counts for adult fish are 7 to 10 + 12 to 19 for *S. chiliensis*[3] and 2 to 3 + 6 to 10 for *S. orientalis*. Some idea can be obtained from the following counts made on several smaller *S. chiliensis* caught off Peru and Chile.

SIZE, mm.	NO. OF GILL RAKERS	SIZE, mm.	NO. OF GILL RAKERS
34	7+1+15	89	7+1+17
36	7+1+15	94	9+1+16
37	4+1+16	106	7+1+15
39	5+1+14	111	8+1+17
41	7+1+15	128	9+1+17
44	7+1+16	129	7+1+15
70	7+1+18	135	7+1+15

CONCLUSIONS

All evidence indicates that spawning of *S. chiliensis* takes place in the warmer season off California, Baja California, Peru, and northern Chile. It appears that it should be possible to distinguish between juveniles of *S. chiliensis* and *S. orientalis* by means of gill raker counts even at a relatively small size.

[3] Author examined 25 specimens of *S. chiliensis* caught off San Diego, California, on September 22, 1959, ranging in length from 330 mm. to 380 mm. The gill raker counts for this group of fish were 7 to 9+1+15 to 18.

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The Distribution of Certain Benthonic Algae in Queen Charlotte Strait, British Columbia, in Relation to Some Environmental Factors

ROBERT F. SCAGEL[1]

IN COMPARISON with the progress in our knowledge of most groups of plants—especially concerning their life histories and distributions—the advances made in marine phycology and marine ecology have been relatively slow. The limited access to living material or to the facilities to maintain the larger marine algae in the living condition for a prolonged period of time, the difficulties of collection—particularly in the subtidal zone—and the lack of any extensive direct economic importance until recent years have all contributed to this slow progress. However, in spite of these difficulties there has been a considerable amount of interest in the marine algae, including a number of studies of their ecology. Although this interest has been fairly widespread in a number of countries, until recently there has been little activity in the field of marine ecology relating to the benthonic algae on the Pacific Coast of North America and nothing of a comprehensive nature has been published for this area. It is an anachronism that this should be so in a region which received such prominence some 50 years ago through the efforts of a pioneer in the field, the late William Albert Setchell (1893, 1917, 1935).

Knowledge of the effect of temperature on the world-wide distribution of plants both horizontally and vertically had developed gradually over a period of many years. However, it was only during the last hundred years that the attention of phycologists was brought to a consideration of the reasons for the observed distributions of the marine algae. The historical development of this trend of thought and investigation has been reviewed by Setchell (1917). Starting over 50 years ago, through a series of papers from 1893 to 1935, Setchell made a noteworthy attempt to explain the world-wide distribution of marine algae, especially of members of the Laminariales on the Pacific Coast of North America, on the basis of latitudinal and seasonal temperature distributions. The physical data available during this early period were limited, but many of the principles set forth by Setchell concerning the distributions of marine algae are as sound now as when they were first proposed. Except for more precise knowledge of the physical and chemical factors of the environment and the distributions of the algae concerned, much of Setchell's ecological work can still be used as a good foundation for further study. Although it was largely a two-dimensional approach to the marine environment, Setchell's work made a significant contribution to the development of marine algal ecology.

Lamouroux (1825, 1826) had suggested the possibility that temperature stratification in the sea might account for the vertical distribution of the marine algae and had considered the effect of tides on intertidal zonations, but this trend to analyze the vertical distribution of the marine algae was not generally taken up in detail until much later. Coleman (1933) was one of the first to emphasize the use of tide levels to account for the vertical distribution of the marine algae in the intertidal zone. In a study in Oregon, on the Pacific Coast of the United States, Doty (1946) has given further evidence for the relationship between the vertical distributions of marine algae and critical tide levels.

A number of lists of marine algae have been published and attempts have been made not only to relate the floras of one area to another, such as that by Okamura (1926, 1932) in the North Pacific, but also to account in a general way for distributions on the basis of ocean currents, such as that by Isaac (1935) in the area around South Africa and by Tokida (1954) in the region of northern Japan. However, there soon followed a decided shift to intertidal studies of regional areas, such as that by Feldmann (1937) in the Mediterranean and Chapman

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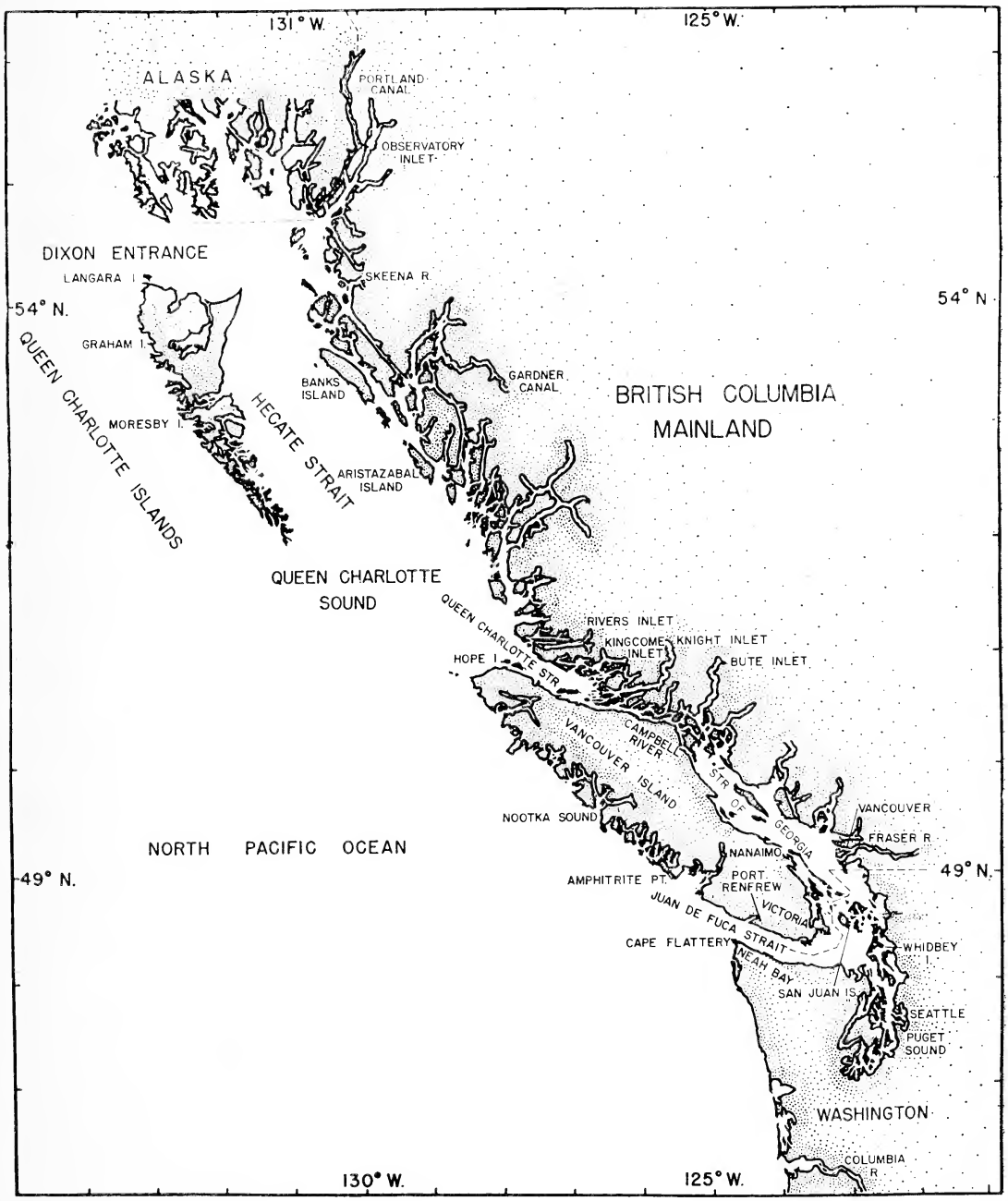

FIG. 1. Map of geographical features of the coast of British Columbia.

(1950) and his students in New Zealand. Some attempts have also been made to describe universal features of intertidal zonation throughout the world (Stephenson and Stephenson, 1949). At the same time there has been a tendency to place greater emphasis on the interrelationships between the various organisms.

Many of these intertidal studies have been of great value as an initial descriptive stage of investigation, and there is a need for further descriptive studies of this type in new and undescribed regions. However, the variety of systems of nomenclature and terms that have been proposed by marine ecologists to describe zonation, associations, and other ecological concepts has frequently only complicated the descriptive study rather than succeeded in explaining the observed phenomena. This has led to some confusion in terminology. It is a debatable point whether there can be such a thing as a universal system of classification beyond a generalized scheme, such as that proposed by Ekman (1935), and it is questionable whether some of the systems proposed can contribute further to progress in marine algal ecology even in regional studies without simplification or clarification. There have been a number of recent comprehensive papers dealing with various aspects of marine ecology which make it unnecessary to dwell at length on a review of the trends that have been followed more recently in marine algal ecology and the results that have been attained (Gislén, 1929, 1930; Feldmann, 1937, 1951; Fischer-Piette, 1940; Chapman, 1946, 1957; Doty, 1957; Hartog, 1959).

Although the shift in emphasis to the interrelationship of organisms was an important one, in some instances this approach has been responsible for excluding adequate concurrent studies of the physical and chemical aspects of the environment. It is for this reason that a case may be made for reassessing the status of marine algal ecology, and a critical evaluation of the steps to be taken to further its progress is timely. Perhaps what may be called a three-dimensional or an oceanographic approach can be used to analyze more precisely various factors in the marine environment and the relationship of these factors to the benthonic algae. Steps in this direction have been made more recently

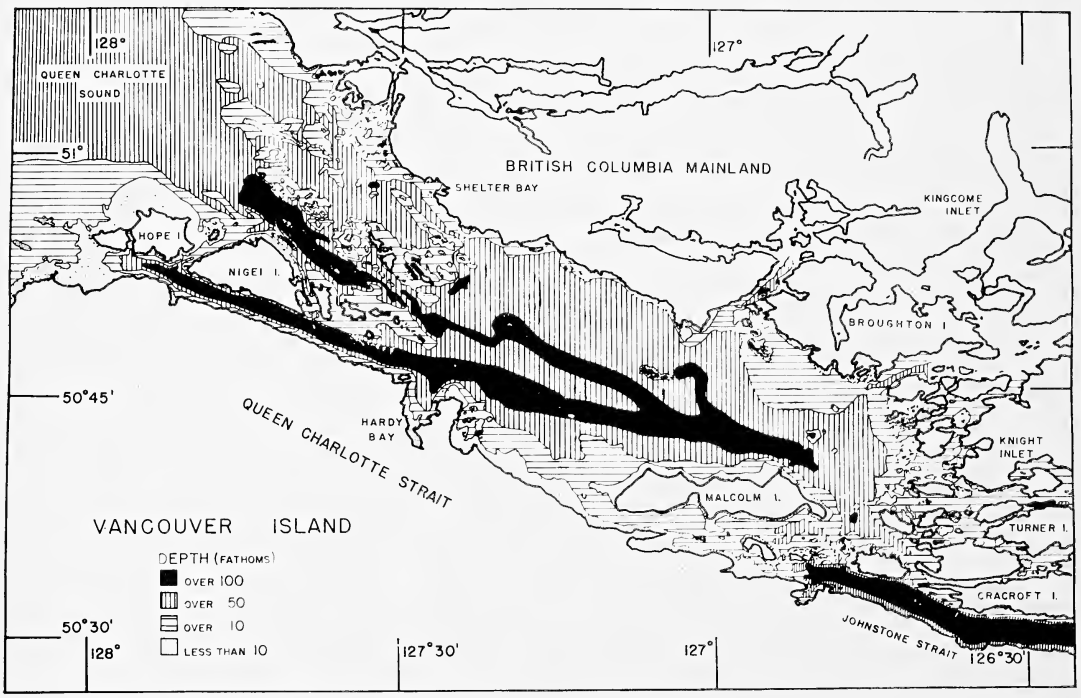

FIG. 2. Map of Queen Charlotte Strait showing depth contours.

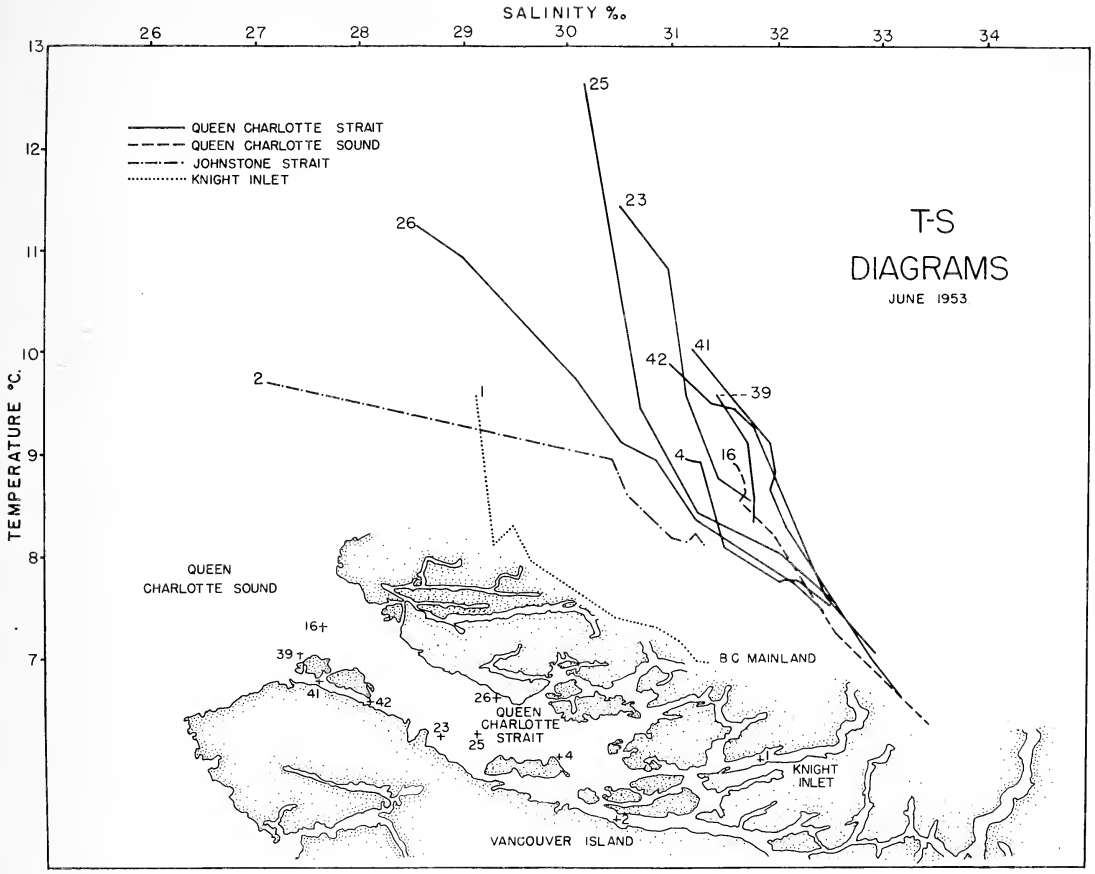

FIG. 3. T–S diagrams for stations in Queen Charlotte Strait and adjacent areas in June, 1953.

with some measure of success by Dawson (1945, 1951) in Baja California, Doty (1946) in Oregon, and Womersley (1956) in Australia.

The physical environment of the sea imposes problems of considerable magnitude which, in contrast to many land environments, presents formidable obstacles such as complex tidal and circulation patterns. In an effort to manipulate or simulate some aspects of this environment, both in the field as well as in the laboratory, the more generally available resources are soon taxed. Thus the methods that have been used in marine algal ecology have, in many instances of necessity, been crudely quantitative, less than ideal experimentally, frequently encumbered by terminology as a result of limited concurrent physical and chemical data, and sometimes they have failed to establish clearly the objectives being sought. As a result most of the efforts in marine algal ecology have been descriptive rather than functional in nature. As in most oceanographic work there is value in an approach from the grosser aspects to the particular. To the oceanographer the most complicated physical or chemical situation to explain may be the smallest unit of the environment with which he is faced. This is partly a problem of instrumentation. However, it is usually much easier to recognize significant discontinuities in properties, such as temperature, salinity, and even plankton distributions, over extensive areas of the ocean than in restricted or local regions. It is also easier to use such information in describing dynamic processes. Hence, it is suggested that more attention should be given to studies of the general distribution of various physical and chemical properties in the marine environment in an attempt to set up some workable hypo-

theses to account for observed distributions of marine algae. In this way we may hope to explain and account for biological phenomena rather than be satisfied by a description of the phenomena or by devising terms to describe them which do nothing more than give names to dynamic aspects of marine ecology much in need of logical explanation. With the recent increased activity in oceanography in the Pacific we may now hope for more abundant and usable data on some of the more general oceanographic properties of the North Pacific. In specific cases, particularly in more restricted areas, the ecologist will be forced to turn more attention to obtaining *in situ* physical and chemical data before further progress can be made.

One can arbitrarily start by summarizing all the factors in the marine environment as geological, physical, chemical, and biological. The way in which these are considered may be somewhat a matter of interpretation. Salinity, for example, may be considered directly, from a chemical standpoint, or indirectly as a physical factor responsible for changes in density and thus contributing to the pattern of circulation. Likewise, the nature of the substratum may be considered indirectly as a geological factor or directly as a physical or mechanical factor restricting or permitting establishment of benthonic organisms because of particle size. There has been much written on some of these aspects of ecological study in special cases, but it is suggested that, in a general over-all reassessment of the environment, an attempt be made to proceed from this more general position to the particular. This approach may initially lead only to the erection of further hypotheses, since the indirect or direct nature of the action of

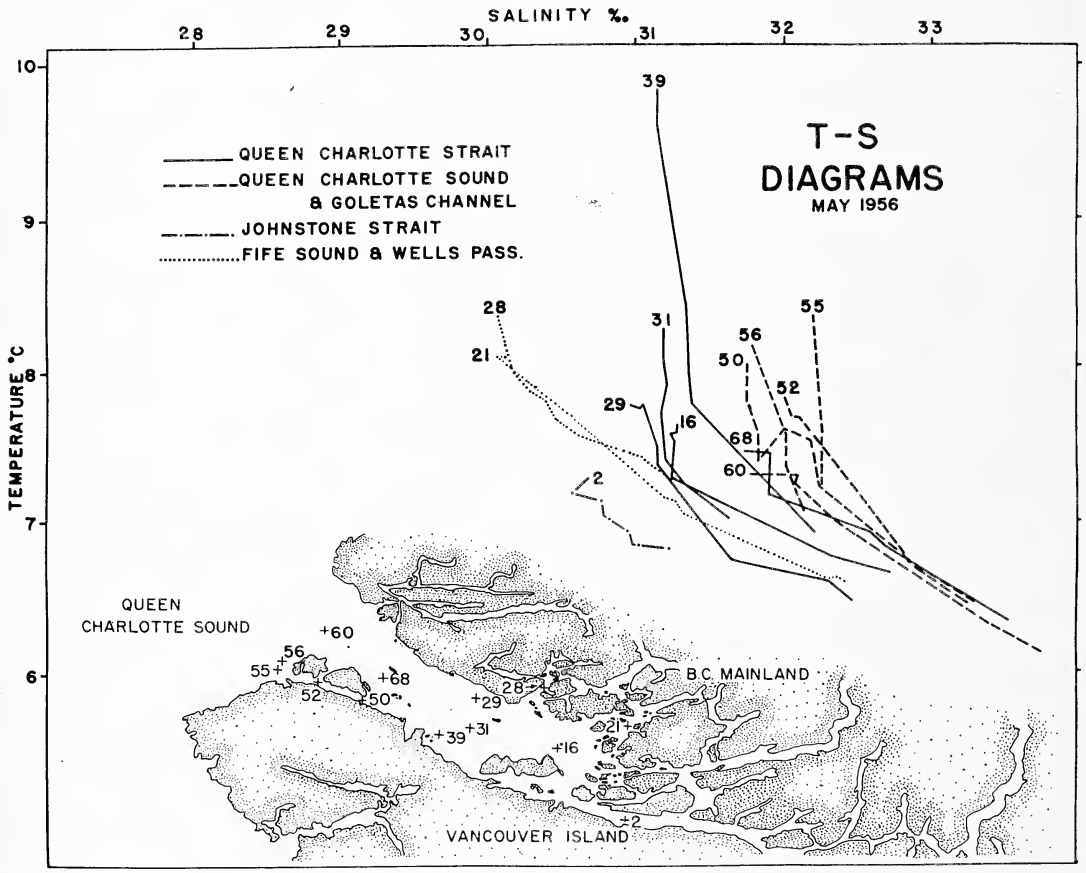

FIG. 4. T–S diagrams for stations in Queen Charlotte Strait and adjacent areas in May, 1956.

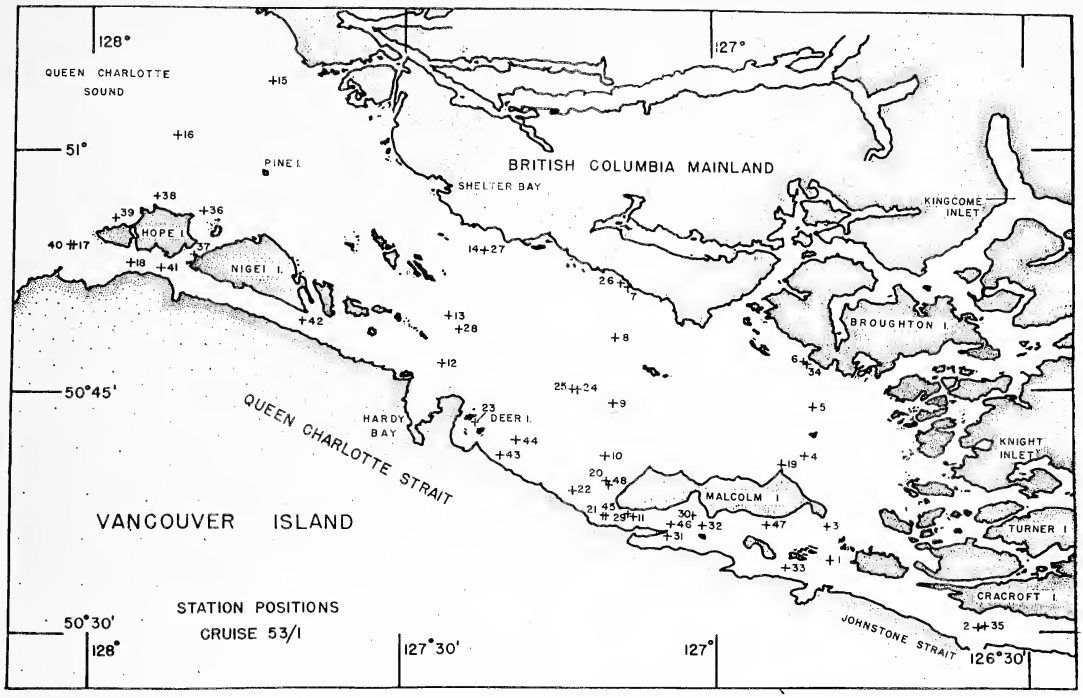

FIG. 5. Map of station positions in Queen Charlotte Strait in June, 1953.

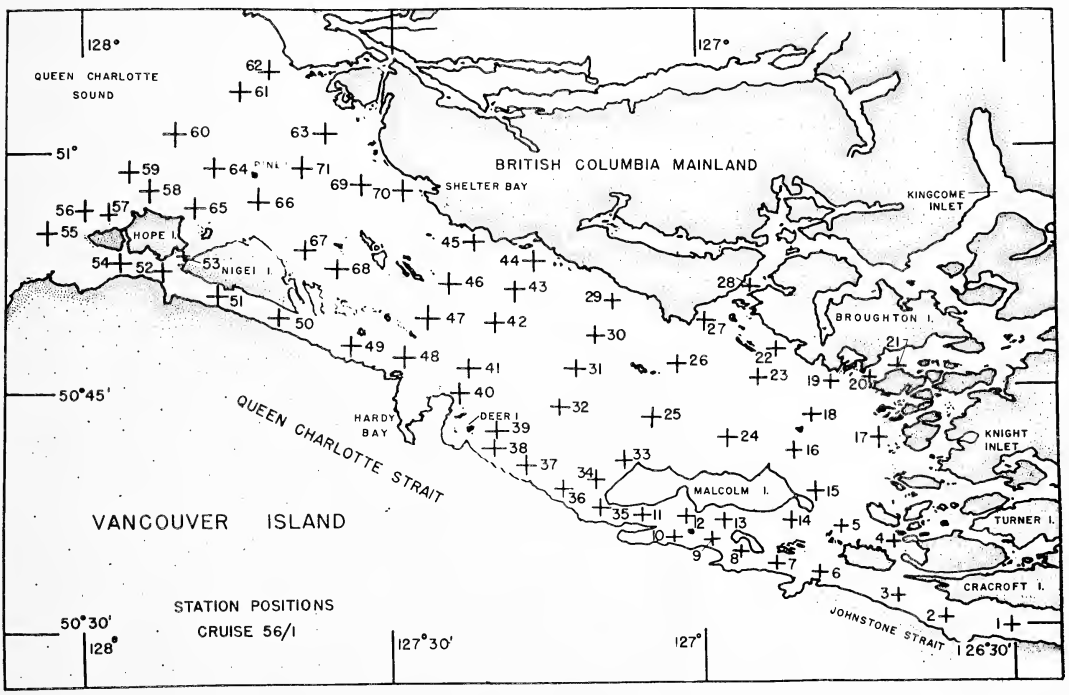

FIG. 6. Map of station positions in Queen Charlotte Strait in May, 1956.

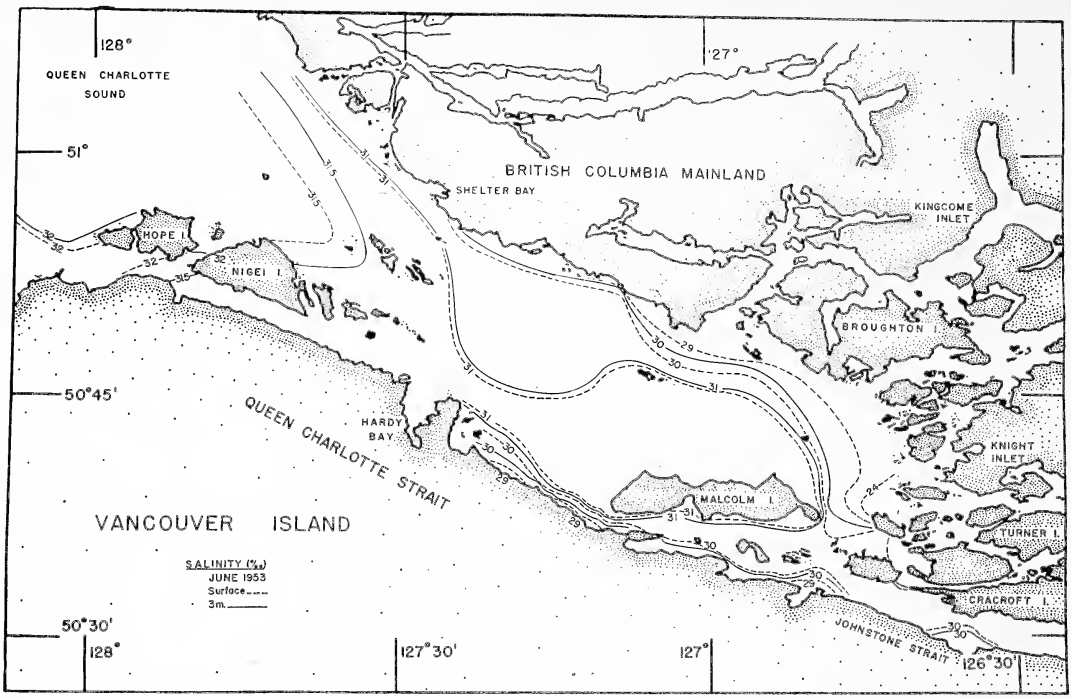

FIG. 7. Salinity distribution in Queen Charlotte Strait in June, 1953, at the surface and at a depth of 3 m.

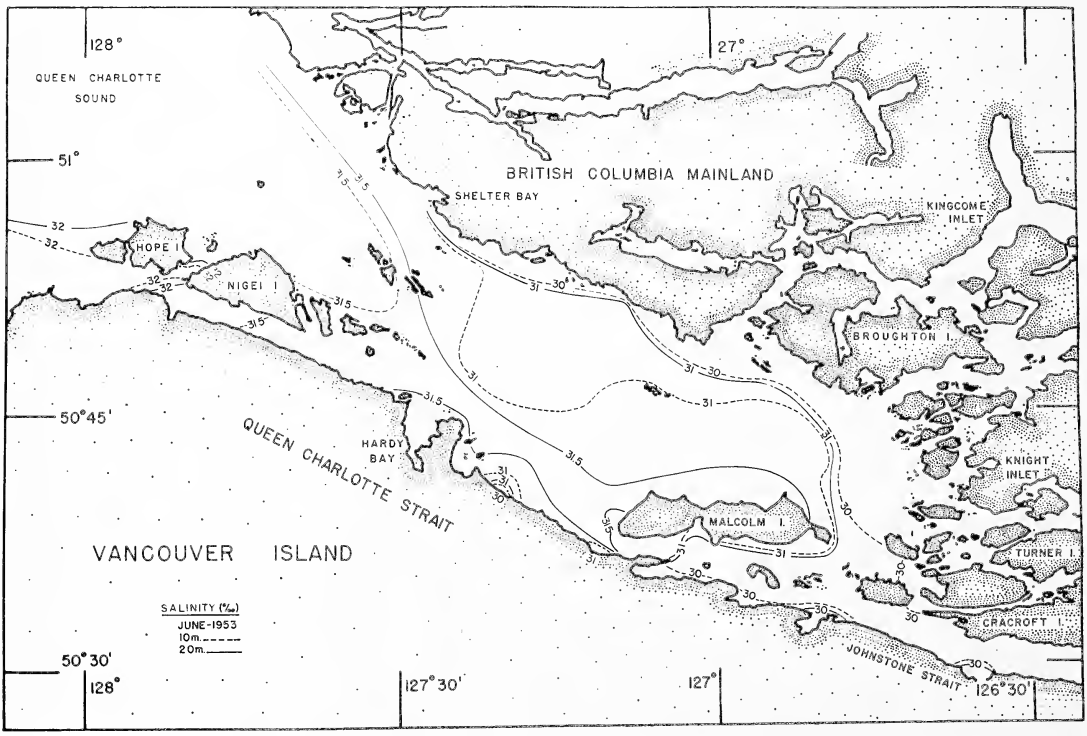

FIG. 8. Salinity distribution in Queen Charlotte Strait in June, 1953, at depths of 10 and 20 m.

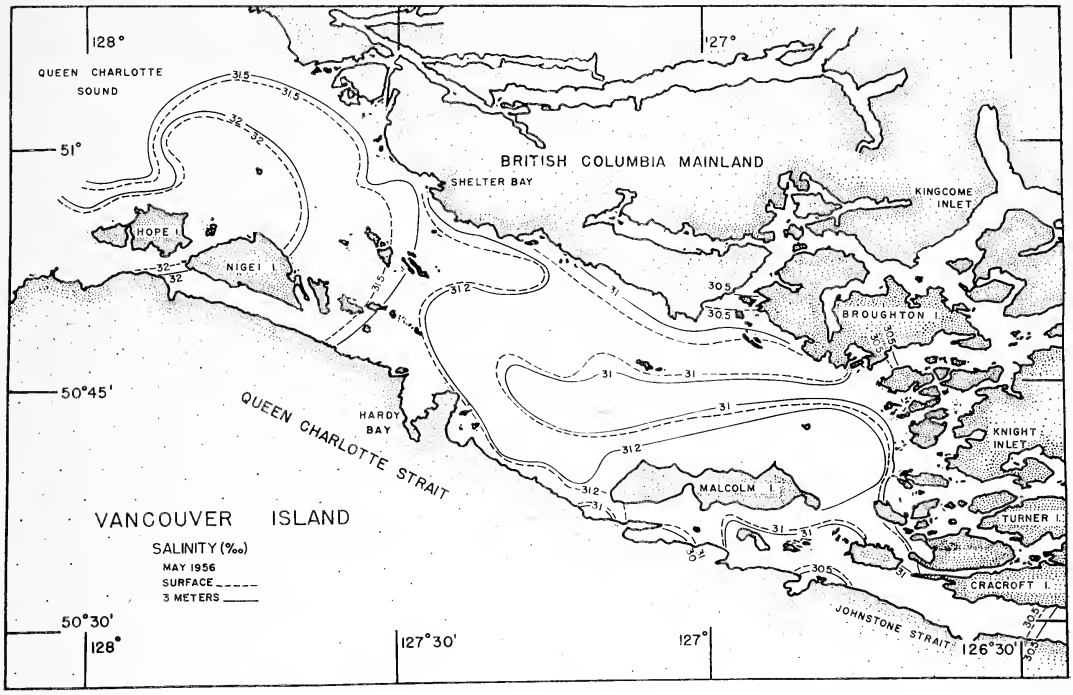

FIG. 9. Salinity distribution in Queen Charlotte Strait in May, 1956, at the surface and at a depth of 3 m.

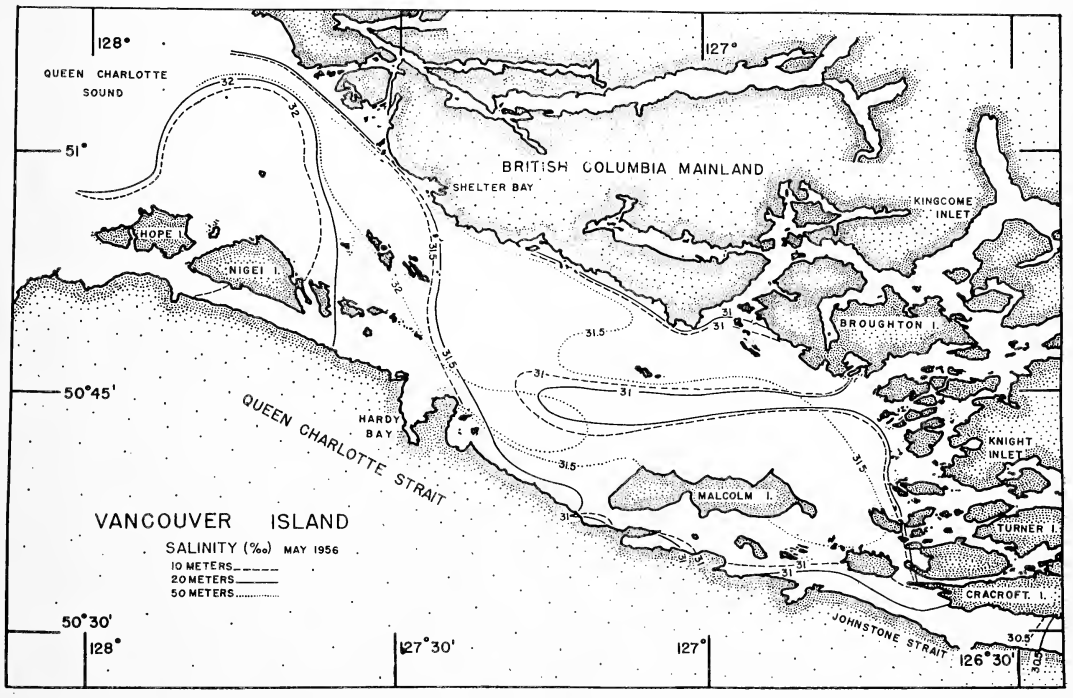

FIG. 10. Salinity distribution in Queen Charlotte Strait in May, 1956, at depths of 10, 20, and 50 m.

any particular factor in the environment may ultimately be established only by experimental work either in the field or in the laboratory. In some regions where the algal flora is well known taxonomically the descriptive aspect can and has been undertaken and the time has come when further progress in such an area can only be expected by undertaking experimental field and laboratory studies. In some regions, even where the flora may be well known, inadequate physical and chemical data militate against further progress and even the advancement of tenable hypotheses. Only when such hypotheses are put forward, based on a correlation of the observational data, can one anticipate and justify embarking on an experimental field and laboratory approach in an attempt to solve problems relative to the distribution of marine algae.

This is the approach that is outlined here in studies on marine organisms and, particularly on the marine algae, being carried out on the coast of British Columbia, some aspects of which will be considered here in detail. As a step in the direction of increasing our knowledge of the entities which comprise the tools of the algal ecologist and of completing this descriptive phase of the study of the marine benthonic algae, an annotated check list has been completed for the coast of British Columbia and northern Washington (Scagel, 1957). Based on this list, further studies are now in progress to augment the existing data on the marine flora of British Columbia, not only on distributions but also on life histories, growth, reproduction, and seasonal aspects. These fundamental studies are basic to all other aspects of ecological research, especially when an attempt is made to use specific organisms as indicators of oceanographic conditions.

Not only does this descriptive phase require an adequate consideration of the taxonomic aspects, but also a complete description of the other factors in the environment is needed. With increased activity recently and currently in general oceanographic studies of the North Pacific by a number of organizations on the Pacific

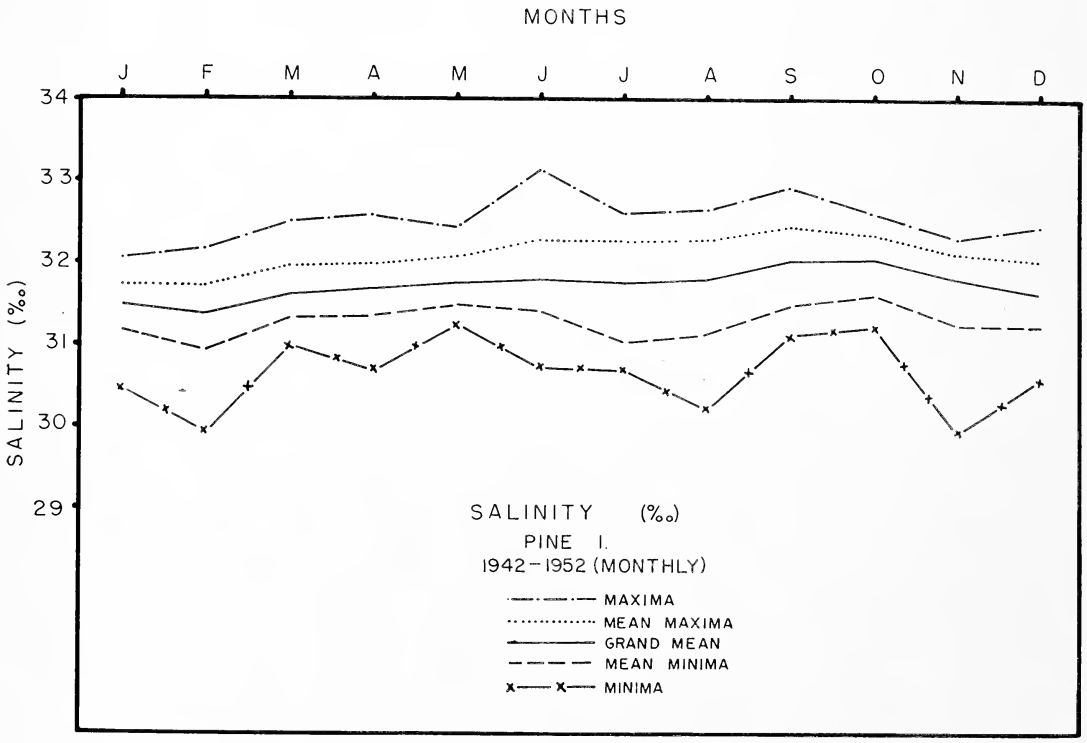

FIG. 11. Monthly salinities at Pine Island for the period 1942–52.

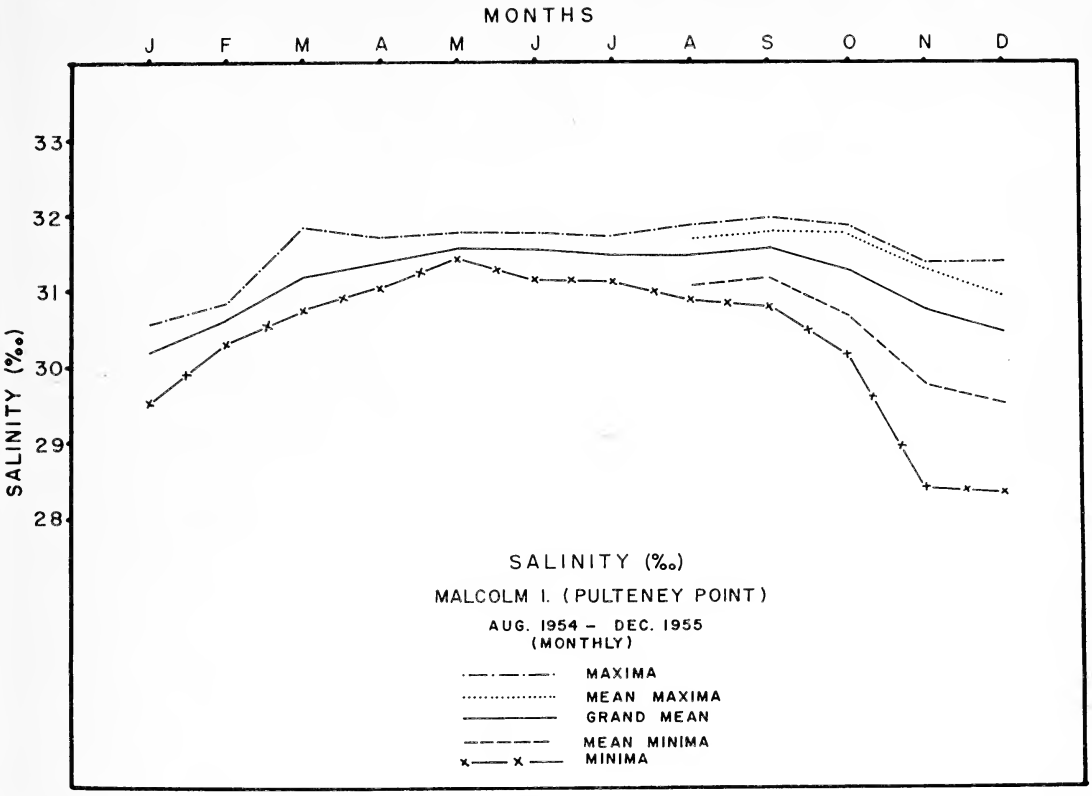

FIG. 12. Monthly salinities at Pulteney Point, Malcolm Island, for the period 1954–55.

Coast of Canada, in Japan, and in the United States, there has resulted a considerable body of scientific knowledge but it is still far from adequate for the ecologist, particularly for one interested in coastal dynamics. Circulation patterns, temperature, salinity, oxygen, and in some areas phosphate, silicate, and nitrate distributions are fairly well known in a broad and general sense, but at the present time these oceanographic data are known in sufficient detail for few restricted areas. Knowledge of the distribution of other chemical constituents and to a large extent even of the plankton composition, distribution, and activity is almost completely lacking. Much more information is needed in order to tackle many problems relating to specific distributions and to set up field and laboratory studies to test hypotheses.

It is already apparent that much can be done experimentally both in the field and in the laboratory with the benthonic algae. Many of the problems encountered by the ecologist dealing with large marine algae present unique culture problems both in the field as well as in the laboratory. Some studies of growth and reproduction, particularly of some of the larger Laminariales, have been done in this region both in the field (Scagel, 1948) as well as in the laboratory. Although the size of many of the cold-water marine algae adds special problems, at least some of the stages can be carried out to the point where transplant experiments can be made from the laboratory into the sea for further study. Transplant experiments of natural populations of juvenile stages, at least of these larger marine algae, even in the case of *Macrocystis*, are quite feasible.

The successful use of the experimental approach in the laboratory is primarily dependent on having facilities for maintaining temperature and light control, although the size of plants may again present certain special problems. Cultures of Laminariales have been maintained in controlled-environment tanks at the

University of British Columbia for as long as a year, during which the complete sexual generations were grown and the young sporophytes reached a length of 14 in., well past the stage where secondary morphological characteristics had developed to a point permitting positive identification. These studies have permitted indisputable identification of the sporophytes to genus, and in some cases to species. The study of cultures in this group suggests that much of the early work on gametophytes in the Laminariales and in fact even on the early sporophytes may be in some question. In most of the early studies reported in the literature, plants were not grown long enough to establish beyond doubt the characteristic secondary morphological features of the sporophytes of the genera from which zoospores were intially obtained. In the presence of contaminating zoospores of other species which can soon supplant the original species under study, there is no other way of establishing that the same species or even the same genus in the Laminariales was obtained in the sporophyte generation succeeding the gametophyte generations in culture.

It would be remiss not to mention much of the worthwhile physiological work that has been done on marine algae and other organisms. However, there is a need for a great deal more physiological work, particularly of the type done by Gail (1918, 1919, 1922) in an attempt to relate physiological processes more specifically and directly to the environment and ecological problems encountered in the field. In physiological studies there is frequently a tendency to proceed more and more deeply into special aspects of the physiological behaviour or the biochemistry of an organism under artificial conditions. Although this information is very often of great value there is a very real need to project back to the field and attempt to explain behaviour under the conditions existing in the natural environment. The statistical approach, as illustrated by Berquist's (1959) revealing study of *Hormosira*, has also been little used as yet.

Almost all of the quantitative aspects of the productivity of the benthonic algae in this area have related to species of economic interest (anon., 1947, 1948*a*; Scagel, 1948; Hutchinson, 1949). These studies have dealt largely with harvestable quantities and distributions, and have contributed little to an evaluation or an explanation, in terms of oceanographic factors, of the causes for this production.

Obviously the ideal of a functional interpretation in the ecology of marine benthonic algae is dependent on an adequate and balanced knowledge of all of the foregoing aspects—of the qualitative and quantitative features of both the organisms and the environment. Many, much needed data are still lacking. An attempt to follow this line of investigation has been pursued on the coast of British Columbia and in a somewhat more restricted area at the north end of Vancouver I. in Queen Charlotte Strait. Further detailed work is in progress in the Strait of Juan de Fuca at the south end of Vancouver I. between Vancouver I. and northern Washington. The study in Queen Charlotte Strait forms the major part of this paper.

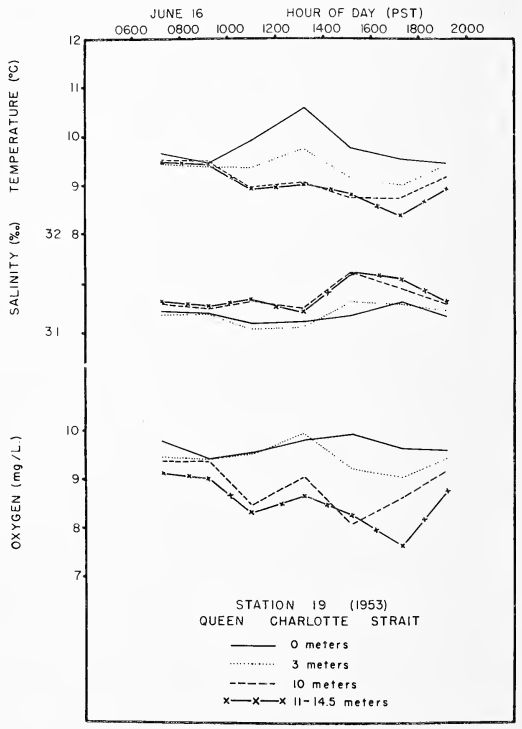

FIG. 13. Fluctuations in temperature, salinity, and oxygen at various depths near Malcolm Island at station 19 (1953).

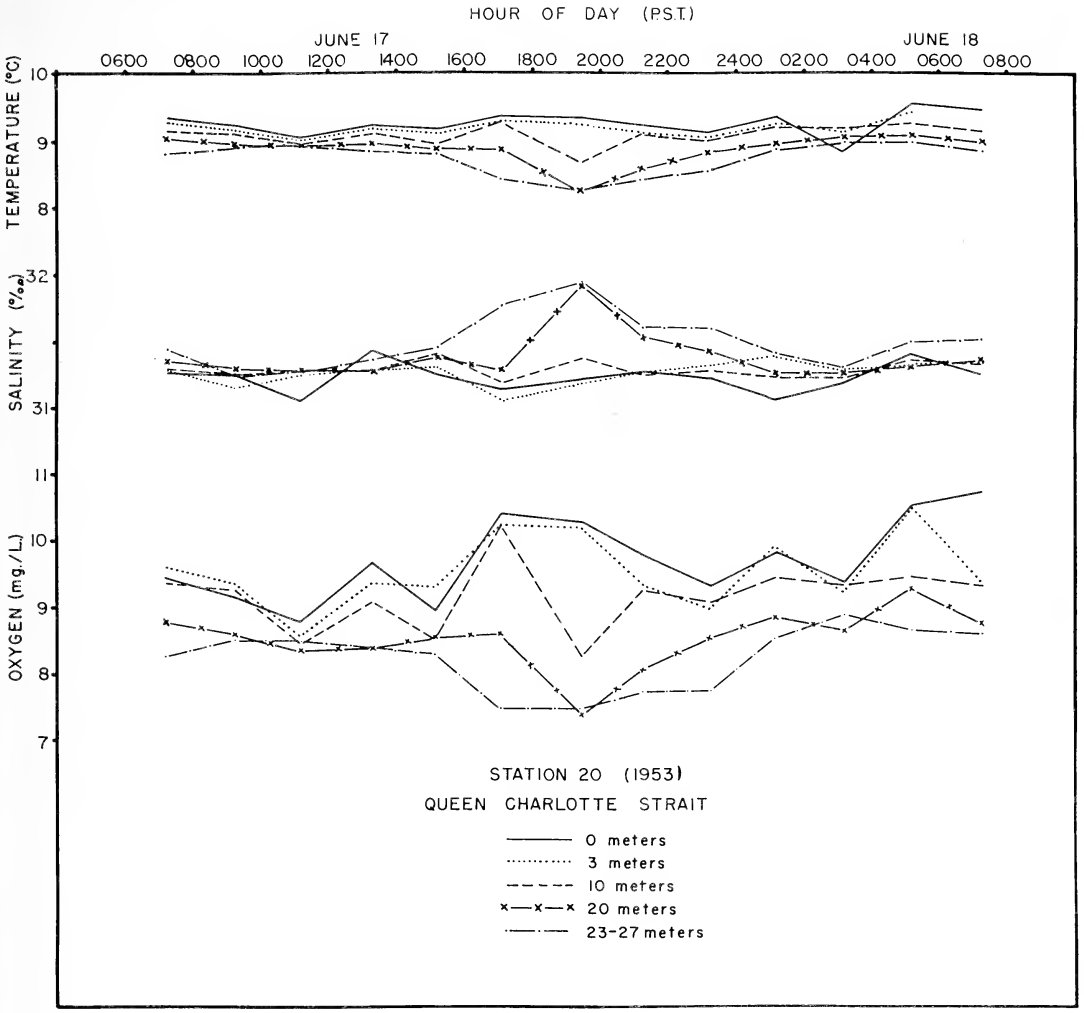

FIG. 14. Fluctuations in temperature, salinity, and oxygen at various depths near Malcolm Island at station 20 (1953).

The more detailed physical and chemical data presented in this paper for the Queen Charlotte Strait area were obtained during two cruises, one (53/1) on the C.G.M.V. "Cancolim II" in 1953 (anon., 1955*a*) and the other (56/1) on the C.N.A.V. "Ehkoli" in 1956 (anon., 1956*a*). The stations occupied during these two cruises are indicated in Figures 5 and 6, respectively. Further less detailed observations were made on a cruise (57/6) in May, 1957, on the C.N.A.V. "Clifton" (anon., 1958). In analyzing the seasonal characteristics and annual fluctuations of temperature and salinity that occur, reference has been made to the data obtained in the area from the daily records (anon., 1944, 1946, 1948*b*, 1949, 1950, 1951, 1952*b*, 1953*a*, 1955*c*, 1956*c*) and data reports of the Hecate Strait Project (anon., 1955*b*, 1955*d*, 1955*e*, 1956*b*) of the Pacific Oceanographic Group. Meteorological data have been obtained from the Meteorological Observations in Canada (anon., 1953*b*), and tidal data were taken from the Pacific Coast Tide Tables (anon., 1952*a*). Chart data have been taken from charts of the Canadian Hydrographic Office and the British Admiralty. Some additional physical and chem-

ical (anon., 1954; Pickard and McLeod, 1953) and geological data (Dawson, 1880, 1881*a*, 1881*b*, 1888, 1897; Bostock, 1948) have been referred to in the literature. Earlier biological observations and collections, which form part of the background for this paper, were made in the area in 1946 (anon., 1947, 1948*a*) and 1947 (Scagel, 1948). The results of a study of the phytoplankton and zooplankton collections which were also made during the same cruises will be presented in a subsequent paper.

GENERAL ECOLOGICAL CHARACTERISTICS OF COASTAL REGION

The Pacific Coast of Canada is ideally suited to a study of benthonic organisms and the effect of oceanographic factors on their distribution both in the intertidal and the subtidal zones. Although the coast of British Columbia (Fig. 1) is only about 600 mi. long, proceeding directly from the Strait of Juan de Fuca to Dixon Entrance, if all its various ramifications are included there is a coastline estimated at about 16,900 mi. in length. The tidal amplitude in this region is great, ranging from about 11 ft. at the southern boundary to nearly 26 ft. at the northern boundary. As a result of thorough mixing in the coastal region the upper zone in this area, except for a few local anomalies, is characteristically rather uniform in temperature at any one period and fluctuations occur within narrow limits. The annual range in temperature of the seawater near the surface is from about 6° to 18°C. On the other hand, because of the runoff from large rivers, especially through the long mainland inlets, there are conditions ranging from practically fresh water at one extreme to full ocean salinity of about 34 ‰ at the other.

Throughout the coast the physical nature of the substratum, ranging from mud and sand at one extreme to solid rock at the other, determines to a large extent the organisms which are found in a specific area. However, a comparison of the flora and fauna on various types of bottom is possible in a number of regions which are otherwise oceanographically rather similar. This permits a correlation of the distribution of a wide variety of plants and animals with other physical and chemical factors of the environment. The oceanographic conditions characteristic of the coast provide an ideal area in which to study the distribution of marine benthonic organisms particularly in relation to salinity over a rather extensive geographic area.

GEOLOGICAL CHARACTERISTICS

General Coast Features

The Coast Mountains of British Columbia, which run along the whole length of the prov-

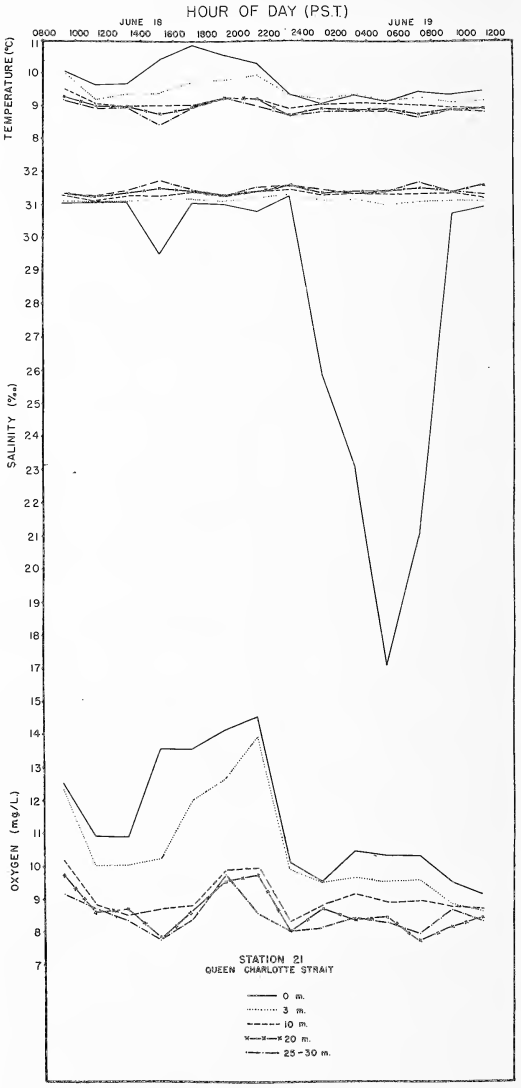

FIG. 15. Fluctuations in temperature, salinity, and oxygen at various depths near the Klucksiwi River at station 21 (1953).

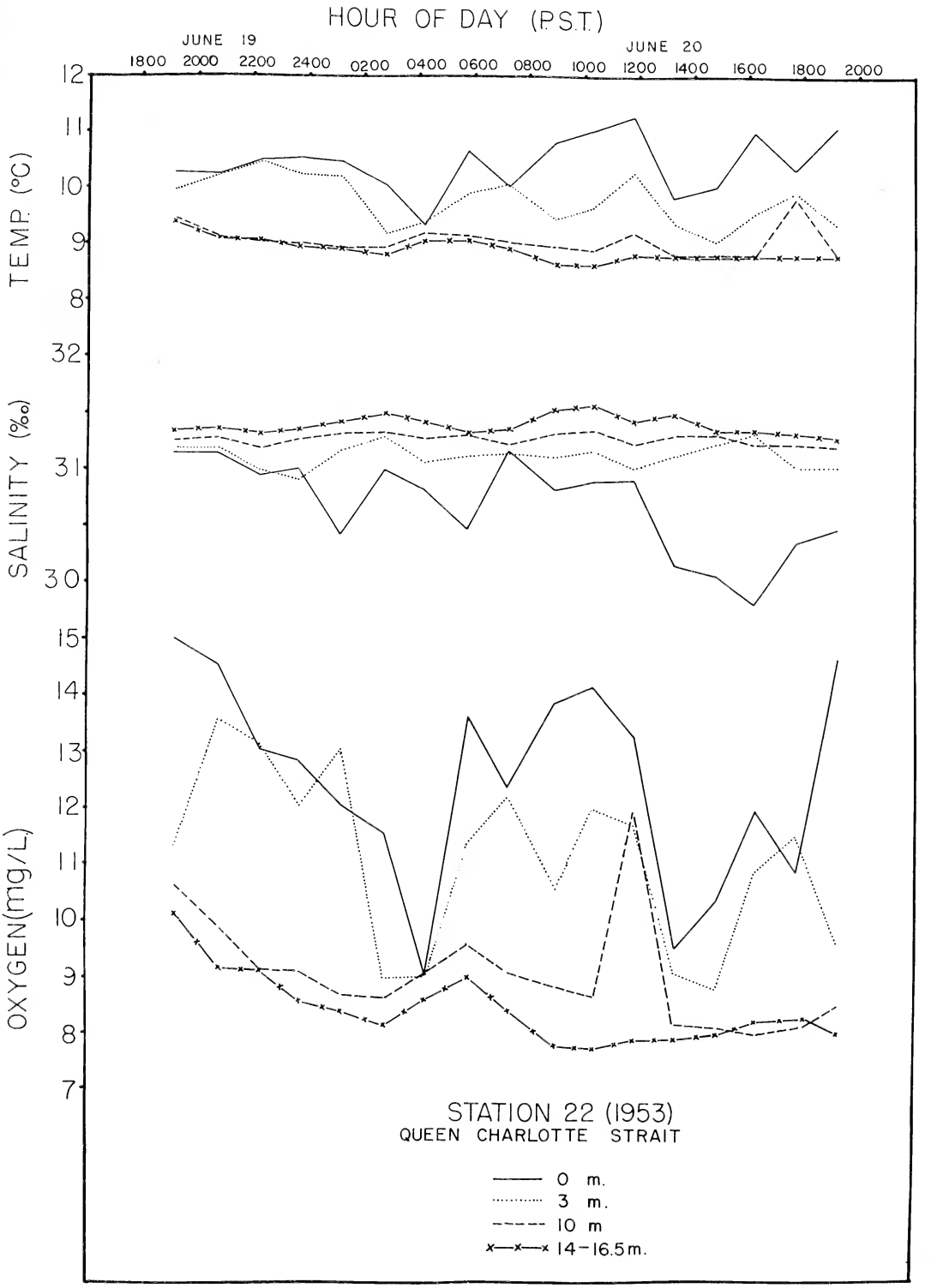

FIG. 16. Fluctuations in temperature, salinity, and oxygen at various depths near the Klucksiwi River at station 22 (1953).

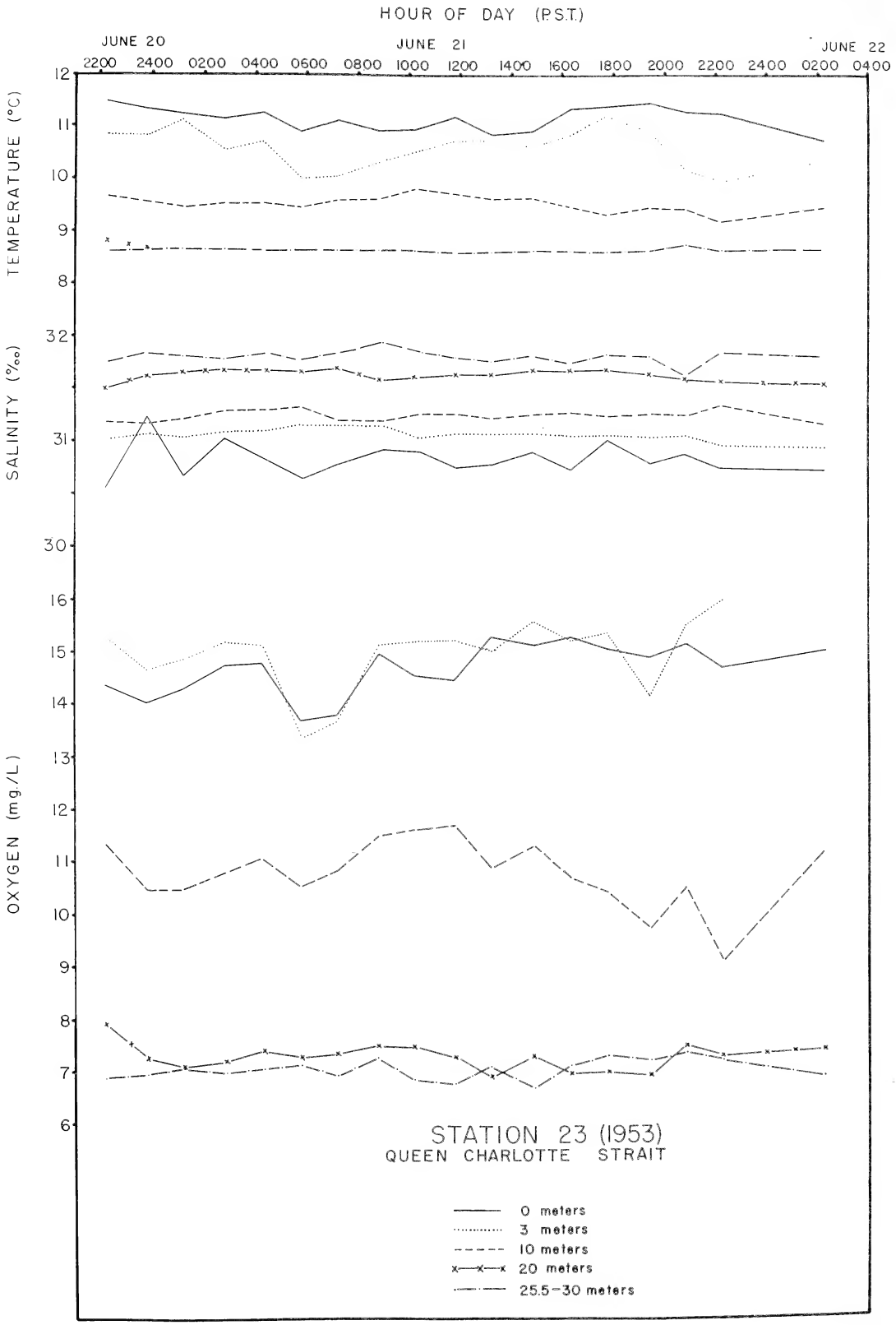

FIG. 17. Fluctuations in temperature, salinity, and oxygen at various depths near Deer Island at station 23 (1953).

ince with an average width of about 100 mi., constitute the mainland coast. Although not as rugged as elsewhere in the Cordillera, the western side of the Coast Mts. rises from the sea precipitously to summits in places exceeding 8,000 or 9,000 ft. Several rivers, which rise in the plateau country to the eastward, flow completely across this range to the Pacific, where the lower parts of their valleys, as well as those of many streams originating in the mountains themselves, continue in the extensive system of fjords along the mainland of British Columbia (Fig. 1). These sediment-filled systems of valleys with steep slopes and numerous deltas can be traced in some places even through the coastal archipelago, which represents a partly submerged margin of the Coast Mountains. West of the Coast Mountains, and in a partly submerged condition, lies another chain, the Insular Mountains, of which Vancouver I. and the Queen Charlotte Islands are projecting ranges. This outer chain stands on the edge of the continental platform with the great depths of the Pacific seaward from it. Between these

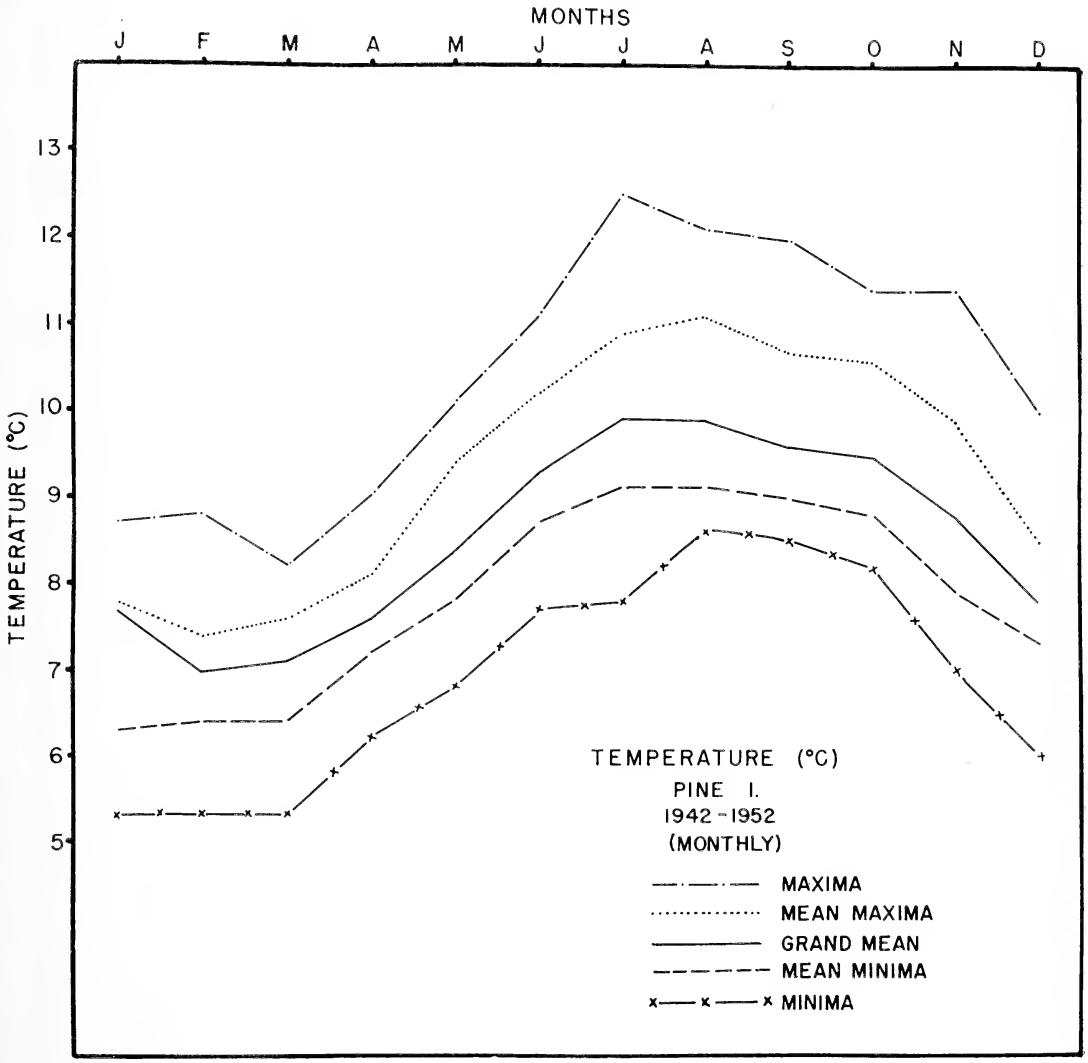

FIG. 18. Monthly temperatures of seawater at Pine Island for the period 1942–52.

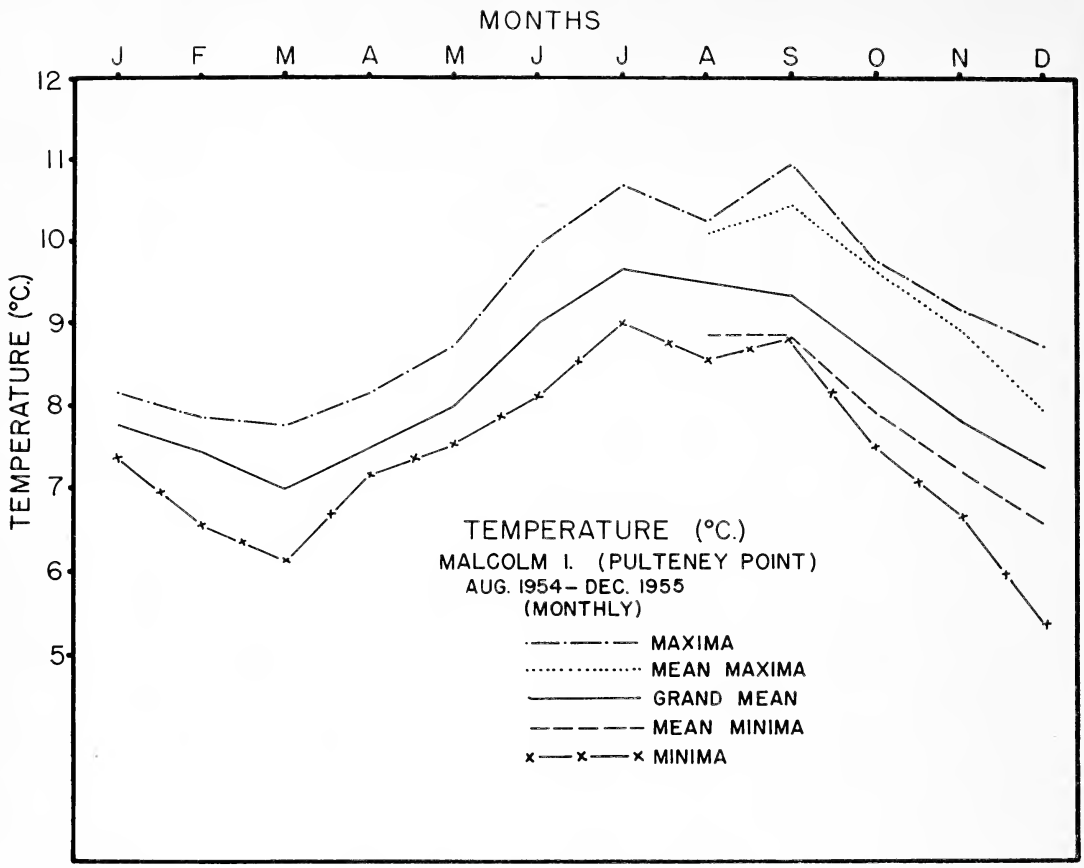

FIG. 19. Monthly temperatures of seawater at Pulteney Point, Malcolm Island, for the period 1954–55.

two ranges lies the Coastal Trough, part of a great depression extending intermittently northwestward from the Gulf of California through the Puget Sound–Williamette lowland and on into Alaska. In British Columbia this great valley is largely submerged and comprises the extensive areas of the Strait of Georgia, Queen Charlotte Strait, Queen Charlotte Sound, and Hecate Strait (Fig. 1).

The Coast Mountains consist largely of Mesozoic rocks ranging from Triassic to early Tertiary and are composed of principally granitic rocks with some included masses of Mesozoic and Palaeozoic strata. The rocks of the Vancouver I. Ranges are composed conspicuously of masses of Triassic and Jurassic lava and volcanic products, lesser contemporaneous sediments with subordinate amounts of later granitic rocks, and marine and continental Cretaceous

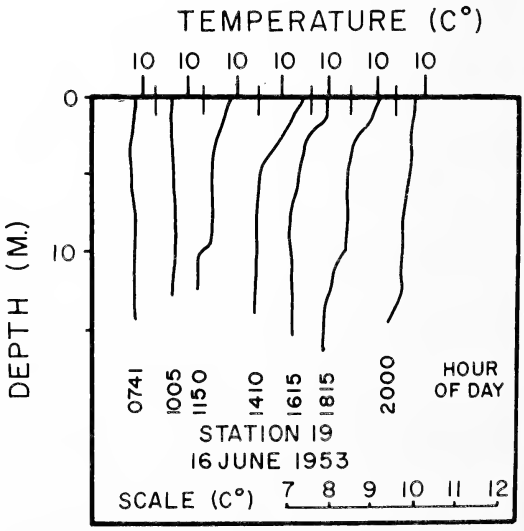

FIG. 20. Temperature profiles at station 19 (1953) near Malcolm Island from bathythermograph traces.

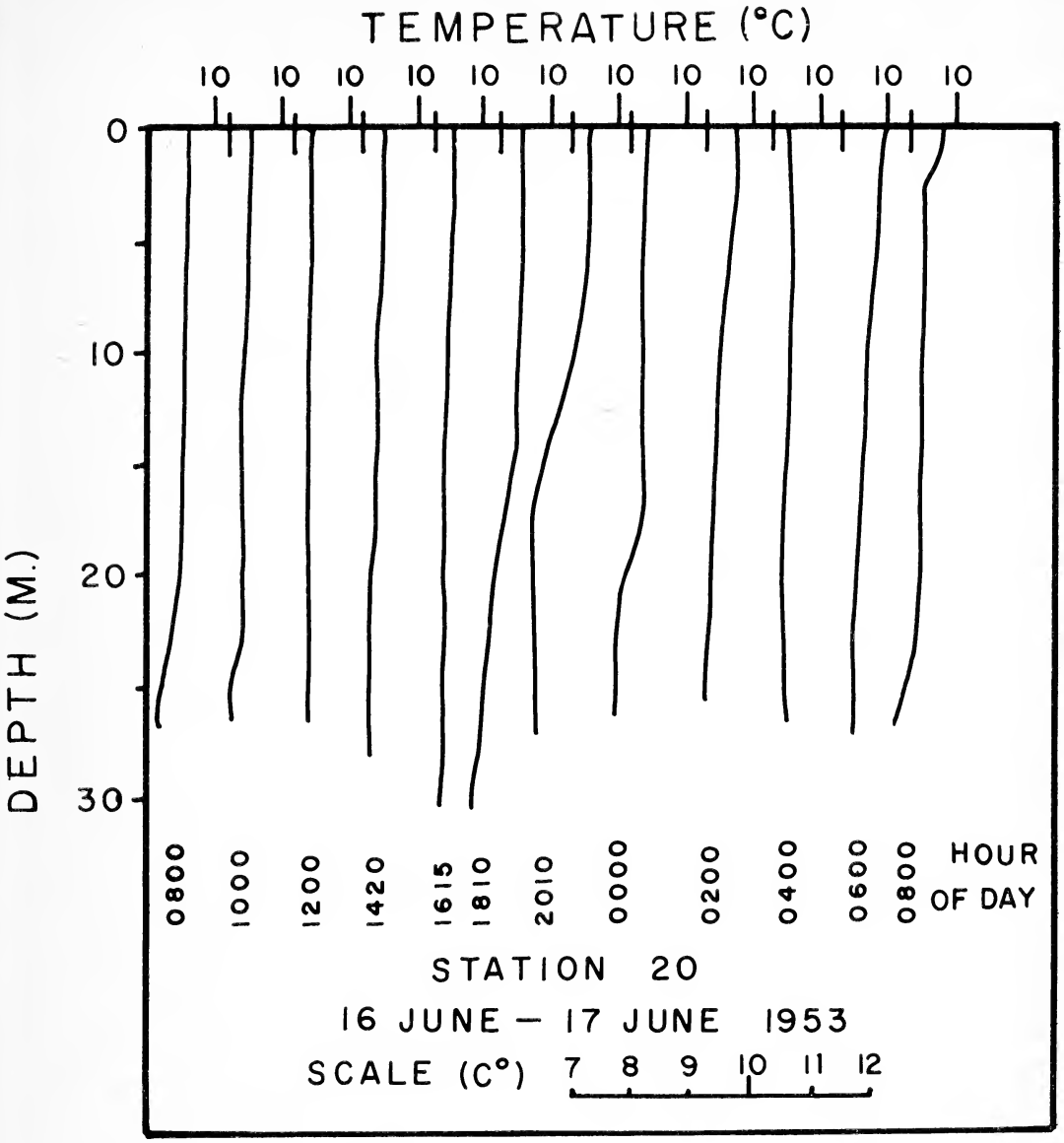

FIG. 21. Temperature profiles at station 20 (1953) near Malcolm Island from bathythermograph traces.

sediments which have participated in its folding. Horizontal Miocene beds occur along some parts of the shore.

General Features of Queen Charlotte Strait

Along the mainland portion of Queen Charlotte Strait (Figs. 1, 3) the rocks are chiefly Jurassic and intrusive, composed of granodiorite, chiefly quartz diorite. Parts of the island groups near the entrance to the Strait, including Hope I. and Nigei I., include some intrusive rocks similar to those on the mainland side, but the major part of the north end of Vancouver I. is composed of Triassic to Jurassic rocks. In this latter region argillites, lavas, tuffs, breccia, sandstones, and limy siltstones are common. A smaller por-

tion of the east coast of Vancouver I. from Hardy Bay southward almost to Johnstone Strait is Cretaceous (chiefly Upper Cretaceous), with shales and sandstones.

The rocks are heavily glaciated throughout almost the whole coastal area. The Queen Charlotte Strait area was heavily glaciated during the Pleistocene, which fact is particularly evident in the vicinity of Deer I., where northwestern slopes are comparatively rough in contrast to the grooved and polished vertical or near vertical faces on southeastern parts. Well-stratified deposits of clays, silts, and sands occur, particularly toward the east end of the Strait and along the Vancouver I. side. Cormorant I., Harwood I., and Malcolm I. are also examples of these deposits. In some places cliffs of these deposits border the shoreline, with extensive accumulations of boulders at the base. In such regions the boulders, which occur in great abundance along the beaches, are probably erratics derived from morainic material.

Although the detailed geology of Queen Charlotte Strait region is not well known supratidally, it is even less well known subtidally. The general features described, however, indicate the wide variety of substrata available for the attachment of benthonic organisms, particularly in the intertidal and shallower subtidal zones. This variety in the physical nature of the sub-

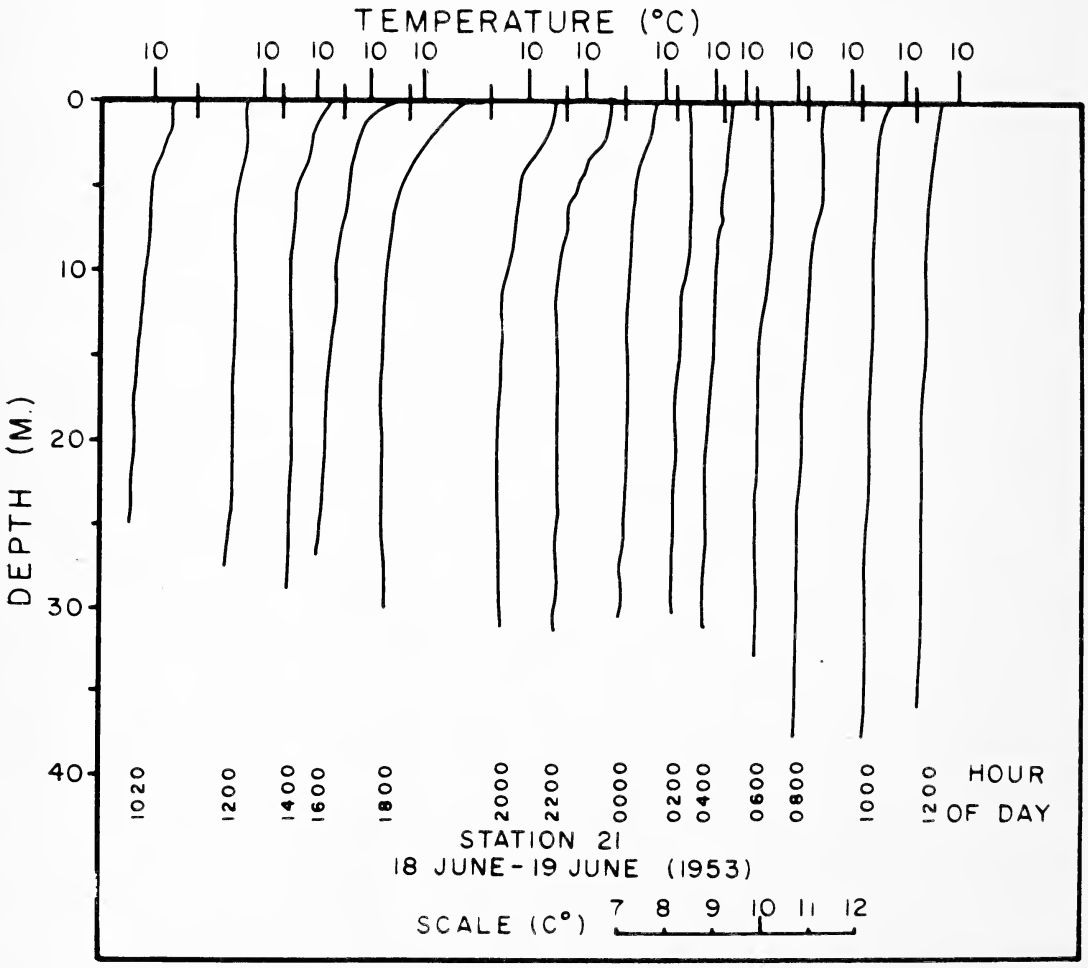

FIG. 22. Temperature profiles at station 21 (1953) near Malcolm Island from bathythermograph traces.

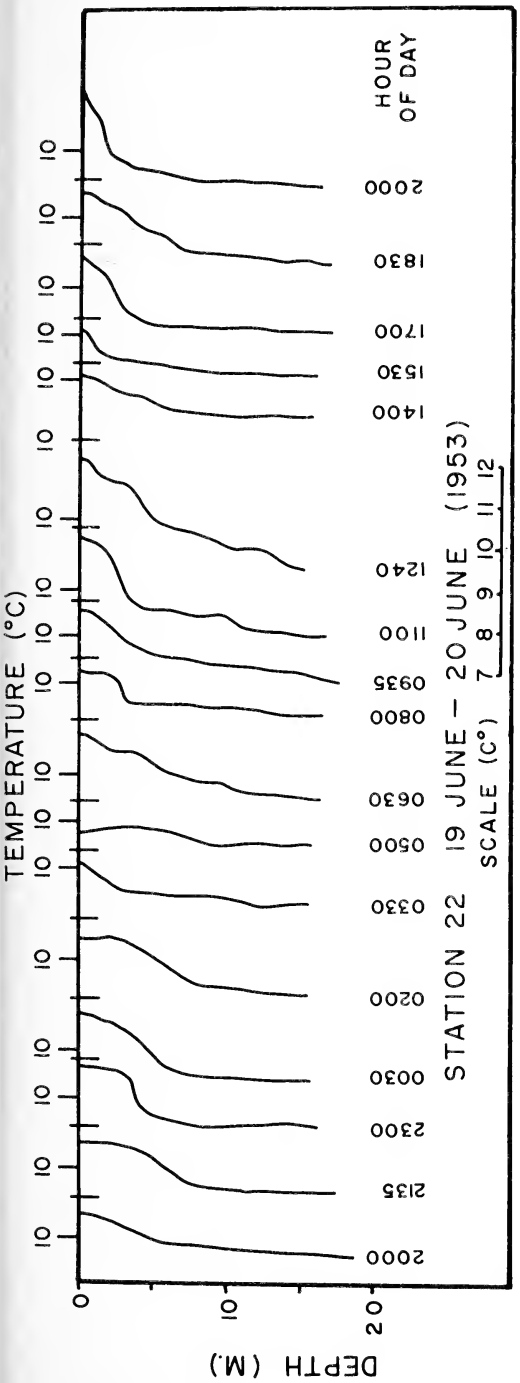

FIG. 23. Temperature profiles at station 22 (1953) near Malcolm Island from bathythermograph traces.

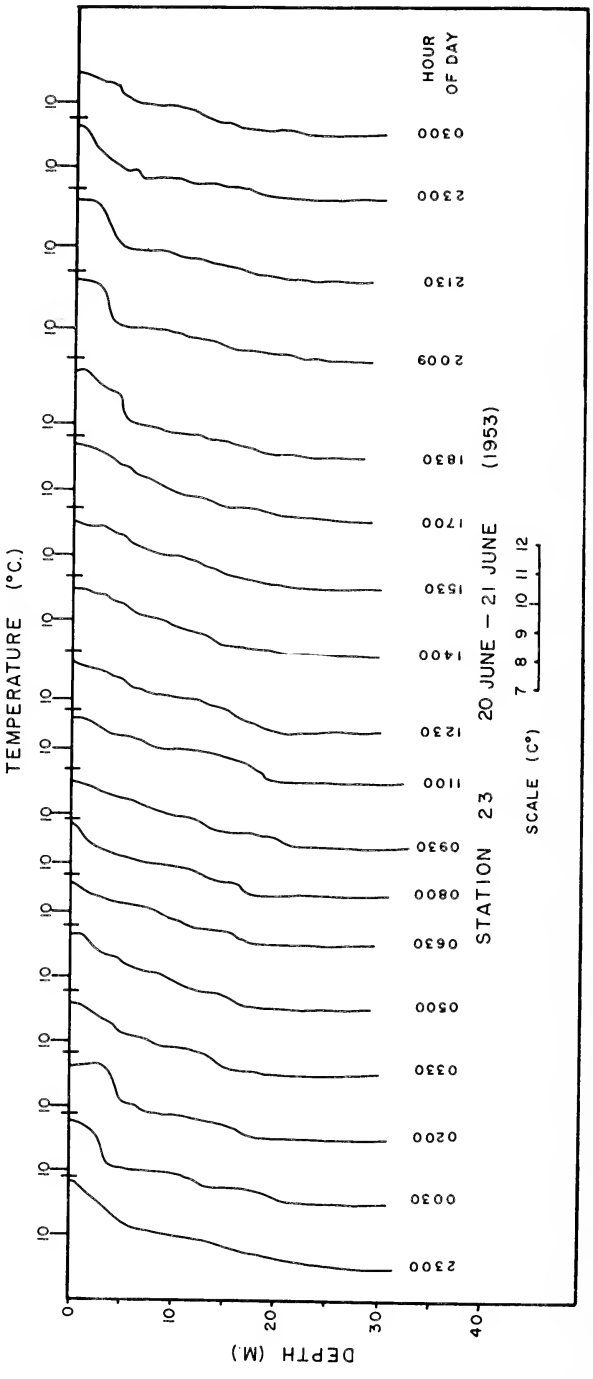

FIG. 24. Temperature profiles at station 23 (1953) near Deer Island from bathythermograph traces.

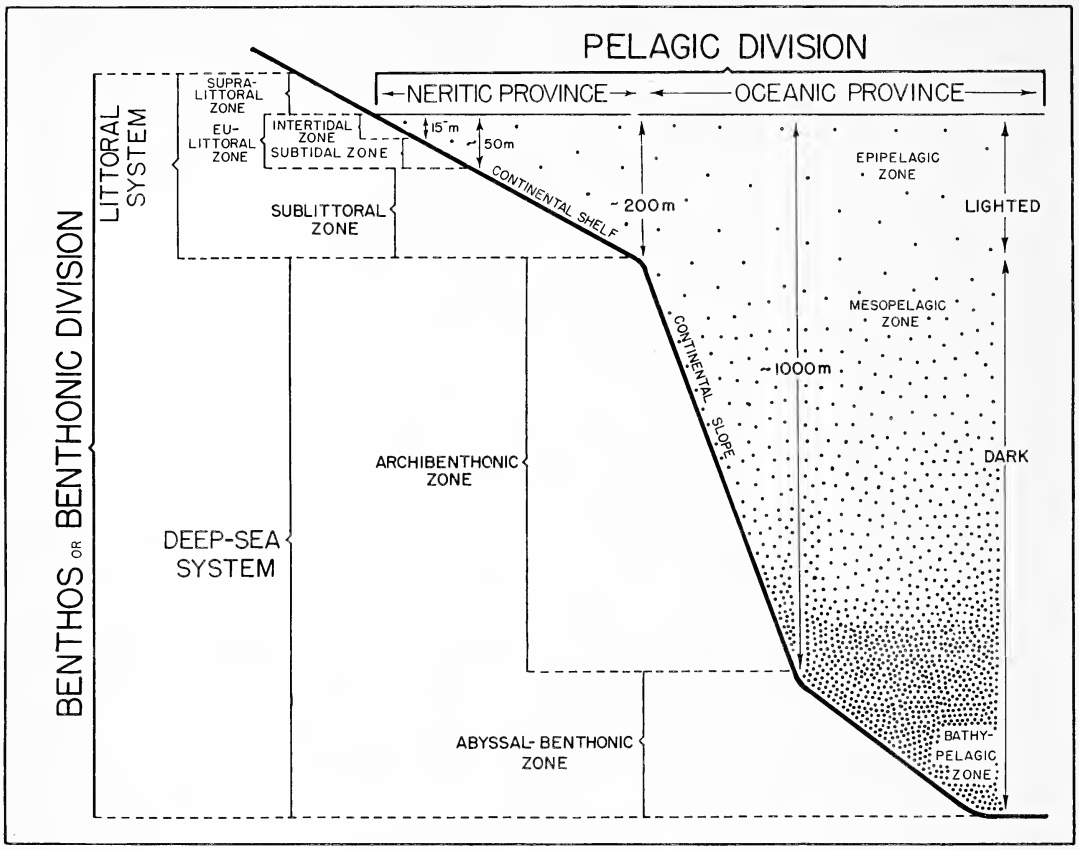

FIG. 25. Diagrammatic representation of regions of marine habitat (modified after Ekman, 1935).

stratum is apparent not only geographically in the area but also vertically. In the deeper water soft mud bottoms predominate but sand and gravel are also found, and in the shallower areas sand, mud, gravel, pebbles, boulders, and solid rock are all found to varying extent, particularly along the Vancouver I. side of the Strait. In the shallower regions, however, a solid rock or bouldery substratum predominates. The nature of this rocky substratum in Queen Charlotte Strait is equally varied. There are igneous as well as sedimentary and metamorphosed substrata. There are basalts, dolerites, trachytic rocks, hard sandstones or quartzites, shales, conglomerates, argillites, fine-grained to crystalline, commonly cherty limestones mixed with feldspathic rocks, and dioritic and granitic fragments are also common.

The preceding brief summary of the general geological features of the area indicates the present status of published knowledge (Bostock, 1948; Dawson, 1880, 1881*a*, 1881*b*, 1888, 1897) concerning the Queen Charlotte Strait region.

Bottom Topography of Queen Charlotte Strait

Although soundings are still incomplete for the area, a study of the bottom topography (Fig. 2) in Queen Charlotte Strait indicates extensive shallows, particularly along the Vancouver I. side of the Strait and around Malcolm I. In this region an abundant and varied intertidal and subtidal flora and fauna are supported. In the central part of the Strait and between Nigei and Vancouver islands (Fig. 2), there are deeper channels exceeding 100 fathoms. The water in these deeper channels is not continuous, however, with the deep waters of the main-

land inlets and Johnstone Strait, and exhibits physical and chemical properties quite distinct from the latter (Figs. 3, 4).

PHYSICAL CHARACTERISTICS

Hydrographic Conditions in Queen Charlotte Strait

The salinity distribution near the surface (Figs. 7–10) in Queen Charlotte Strait suggests a general circulation in a counter-clockwise fashion. The runoff from the mainland inlets along the north shore and at the east end of the Strait, particularly from Knight Inlet at the east end, contributes large volumes of fresh water which tends to move seaward at the surface, mixing as it progresses along the north shore into Queen Charlotte Sound with the deeper more saline water below. The more saline water from the open ocean and Queen Charlotte Sound moves into the Strait centrally as well as along the Vancouver I. side of the Strait and along the north side of Malcolm I. The intrusion of high salinity water along the deep channels in the central part of the Strait is also apparent. This general pattern of salinity distribution, with fluctuations to varying degrees near the surface, is pronounced in the upper zone to a depth of at least 20 m. (Figs. 7–10).

Although strong winds may assist in the movement of water near the surface there is clear evidence at times of the movement of water against the wind and there are strong tidal currents throughout the region. The cur-

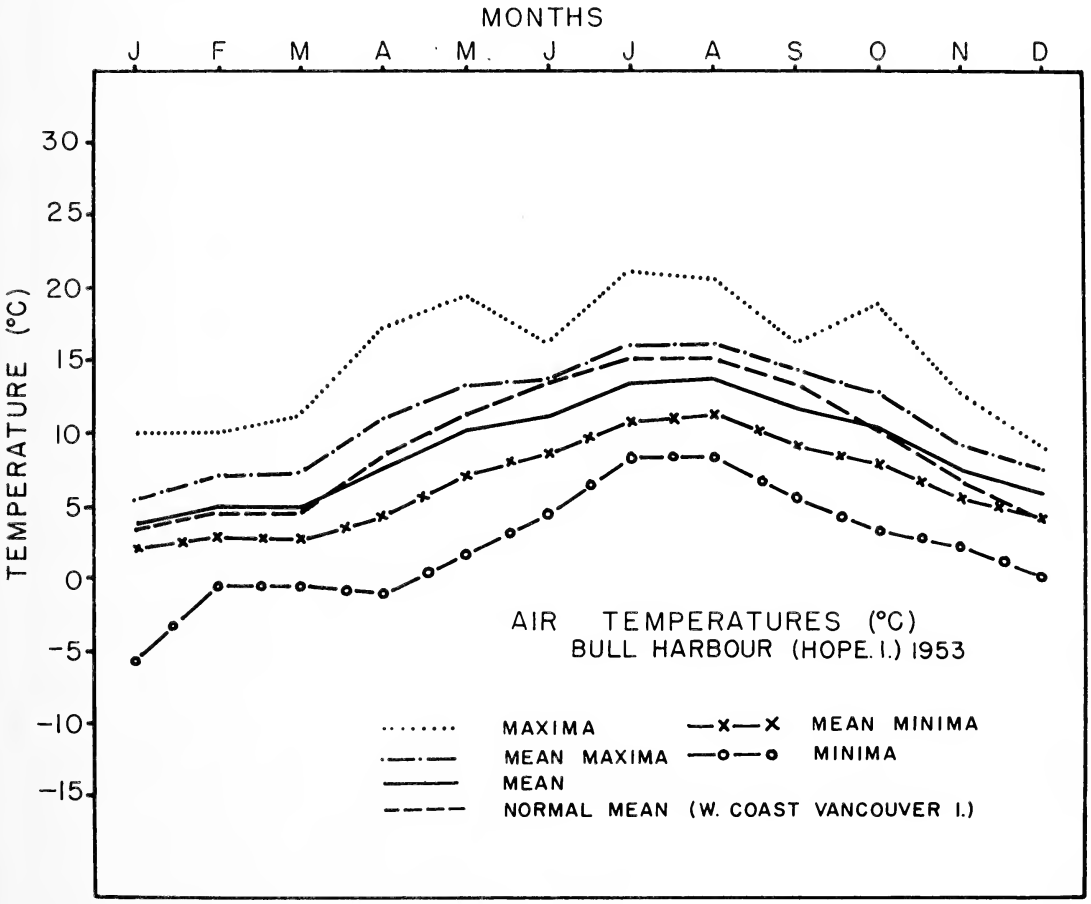

FIG. 26. Monthly air temperatures at Bull Harbour, B. C., for 1953.

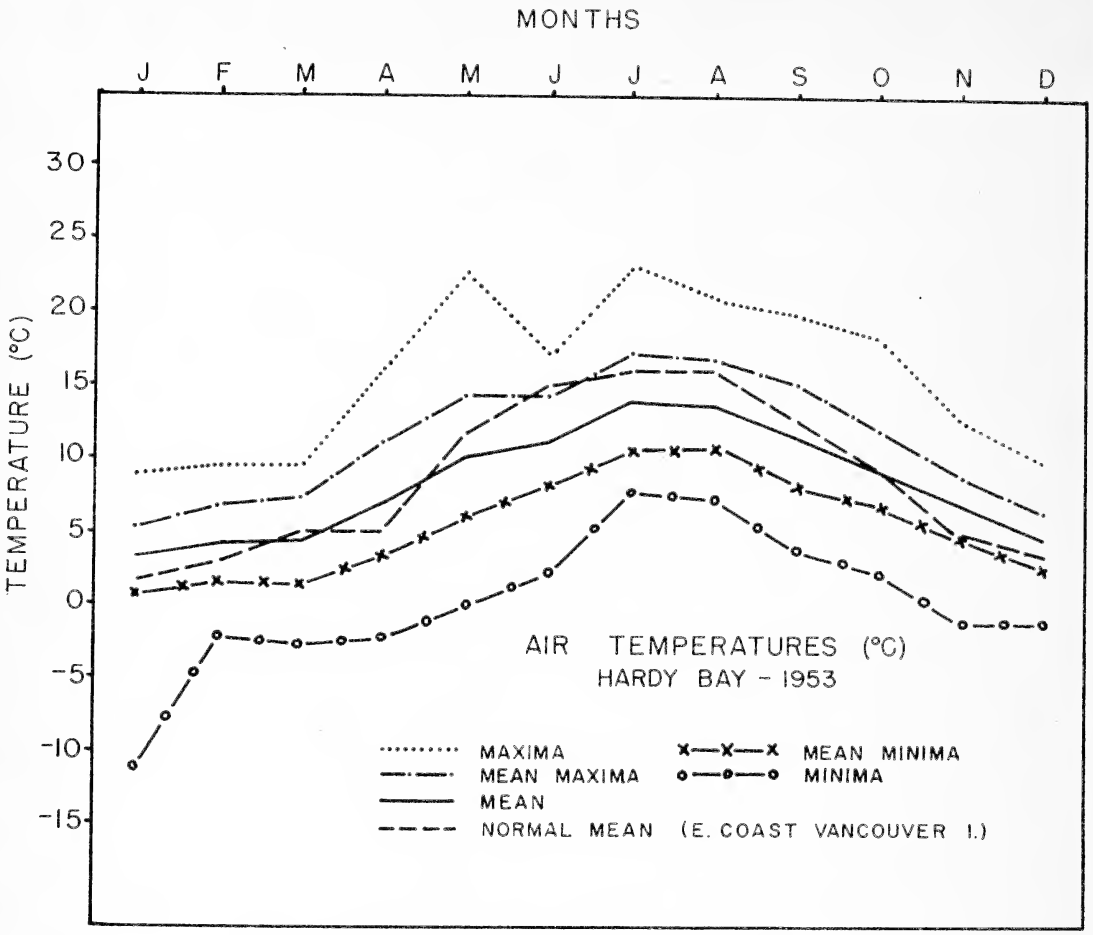

FIG. 27. Monthly air temperatures at Hardy Bay, B. C., for 1953.

rent velocities involved vary considerably but at times may reach at least 80 cm/sec from near the surface to a depth of 20 m., and in deeper portions of the Strait, although generally much less, they may attain as much as 57 cm/sec at a depth of 125 m.

An analysis of surface salinity data over a 10-year period (Fig. 11) from Pine I. Lighthouse, which is near the entrance to Queen Charlotte Strait, indicates a salinity maximum of about 33 ‰ and a minimum of about 30 ‰, with an annual mean of 31.75 ‰. Although this station is not characteristic of the Strait itself, the data available probably give a reasonable approximation of the annual salinity fluctuations for the Strait. Insufficient data are available from Pulteney Point on Malcolm I. to analyze the seasonal fluctuations more precisely in the central region of the Strait, but for the period available (Fig. 12) a range of about 28 ‰ to 32 ‰ with an annual mean of 21.50 ‰ is indicated.

Seasonal data indicate that near the surface the distribution of salinity throughout the year follows the same general pattern, decreasing toward the mainland and being higher along the Vancouver I. side of the Strait. At any one point, however, there is a general decrease in salinity in time from the maximum in April to a minimum in midsummer, when the maximum runoff from the mainland inlets occurs. The winter salinity may be somewhat modified near

the surface during the period of maximum precipitation, which may reduce salinity near the surface.

The minor extent of fluctuations that occur in the salinity distribution in the upper 20 m. is indicated by data taken at a number of anchor stations (Figs. 13–17). These fluctuations are greatest at or near the surface and, in certain instances, as near the Klucksiwi River (Fig. 15), show the influence of fresh-water inflow of a more localized nature.

A comparison of the temperature–salinity characteristics of various parts of the Strait and the connecting bodies of water by means of T–S diagrams (Figs. 3, 4) indicates the discreteness of the water masses typical of Johnstone Strait, mouth of Knight Inlet, and Queen Charlotte Sound. The T–S diagrams for Queen Charlotte Strait indicate a characteristically intermediate condition between these extremes in properties of temperature and salinity for the greater part of the Strait.

An analysis of surface temperature data over a 10-year period (Fig. 18) from Pine I. Lighthouse, which is near the entrance to Queen Charlotte Strait, indicates a temperature maximum of about 12°C. and a minimum of about 5°C., with an annual mean of 8.6°C. Although this station, as already indicated, is not characteristic of the Strait itself in all respects, it probably gives a reasonable approximation of the annual temperature fluctuations. Insufficient data are available from Pulteney Point on Malcolm I. to analyze more precisely the seasonal

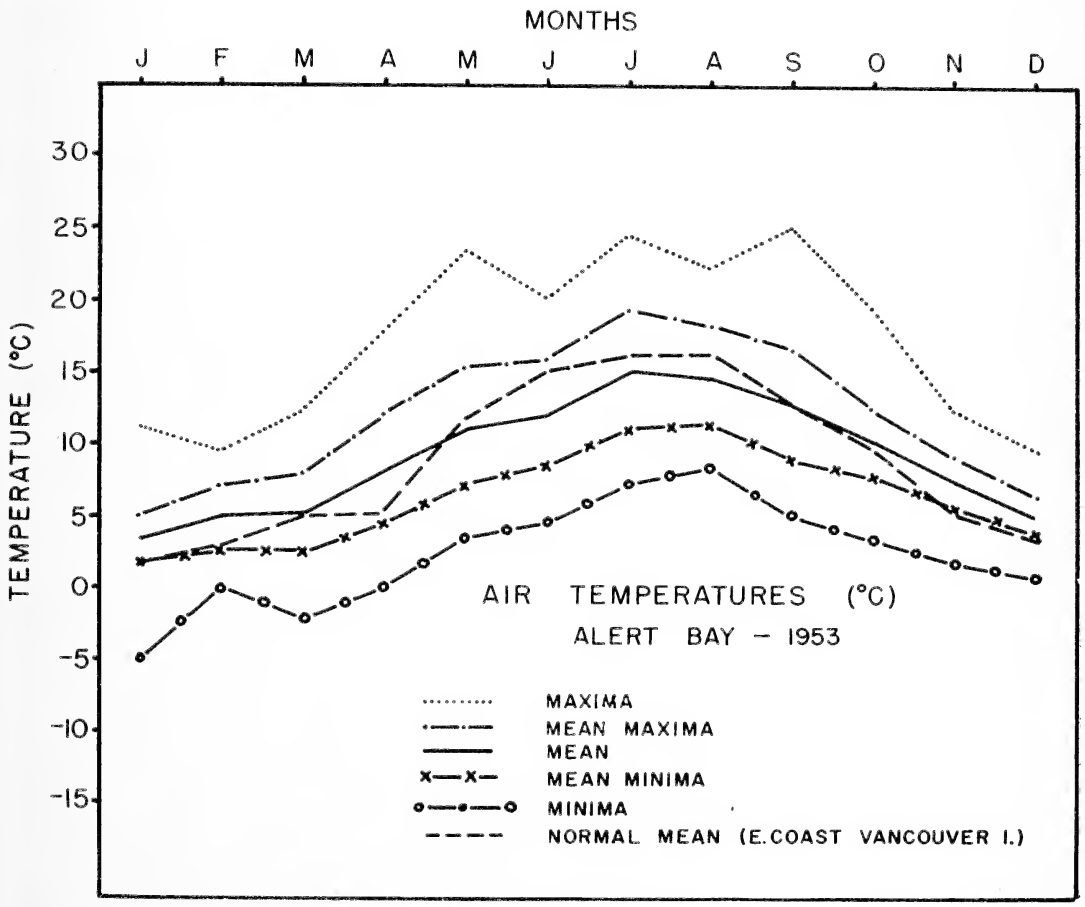

FIG. 28. Monthly air temperatures at Alert Bay, B. C., for 1953.

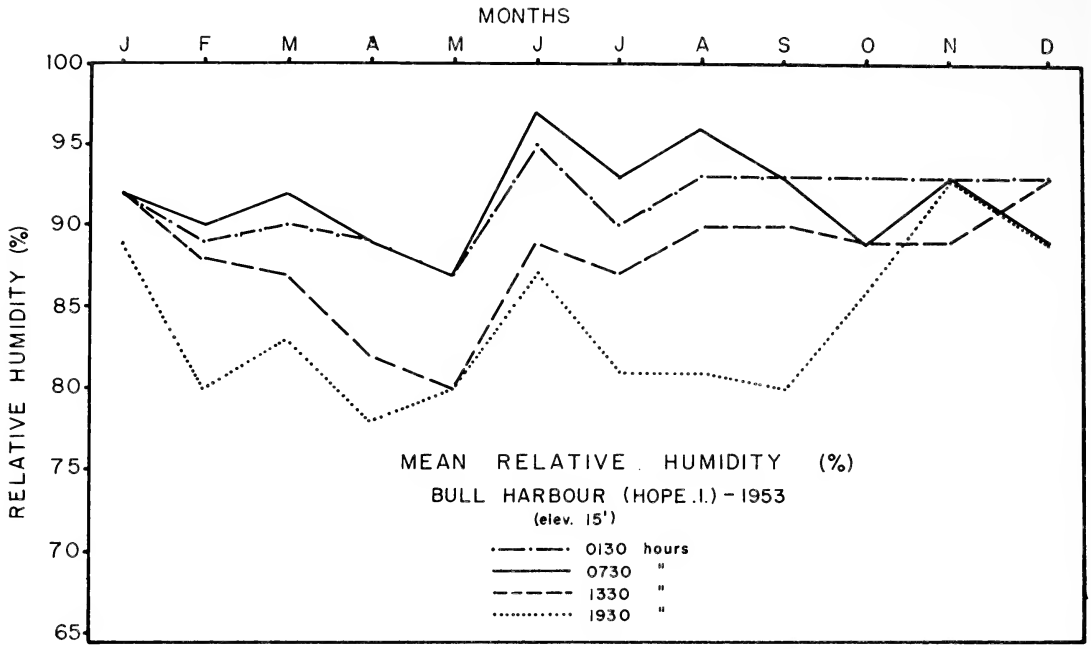

FIG. 29. Monthly relative humidity at Bull Harbour, B. C., for 1953.

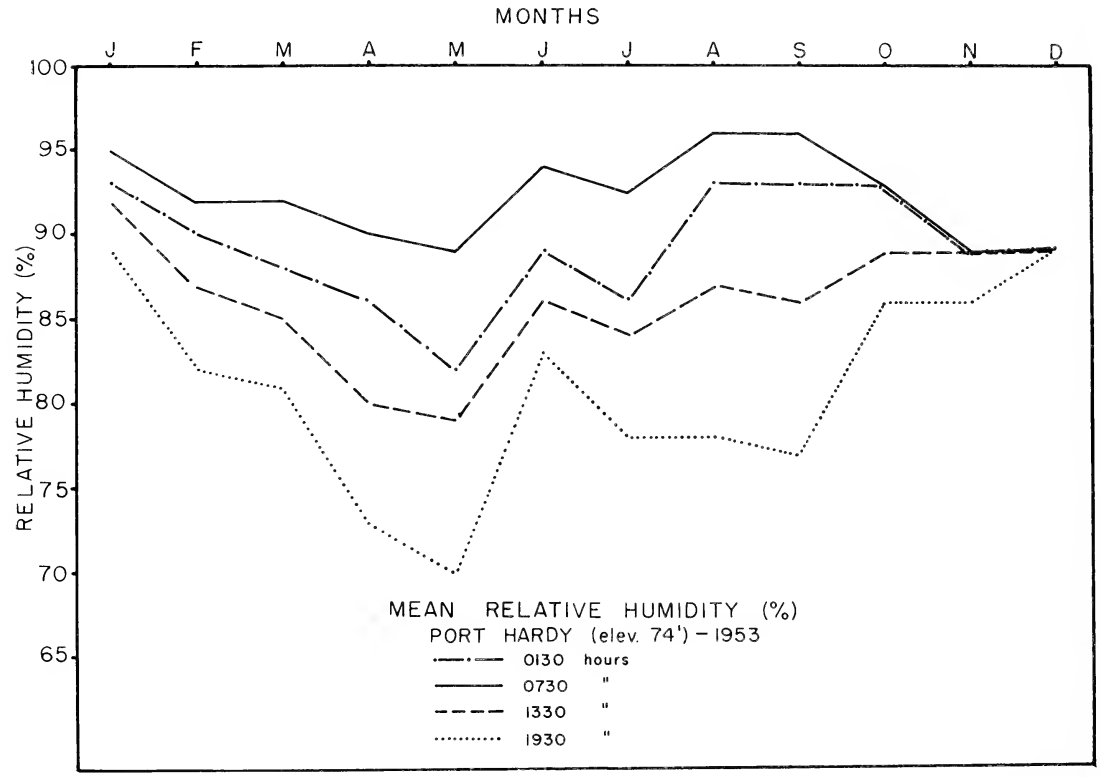

FIG. 30. Monthly relative humidity at Port Hardy, B. C., for 1953.

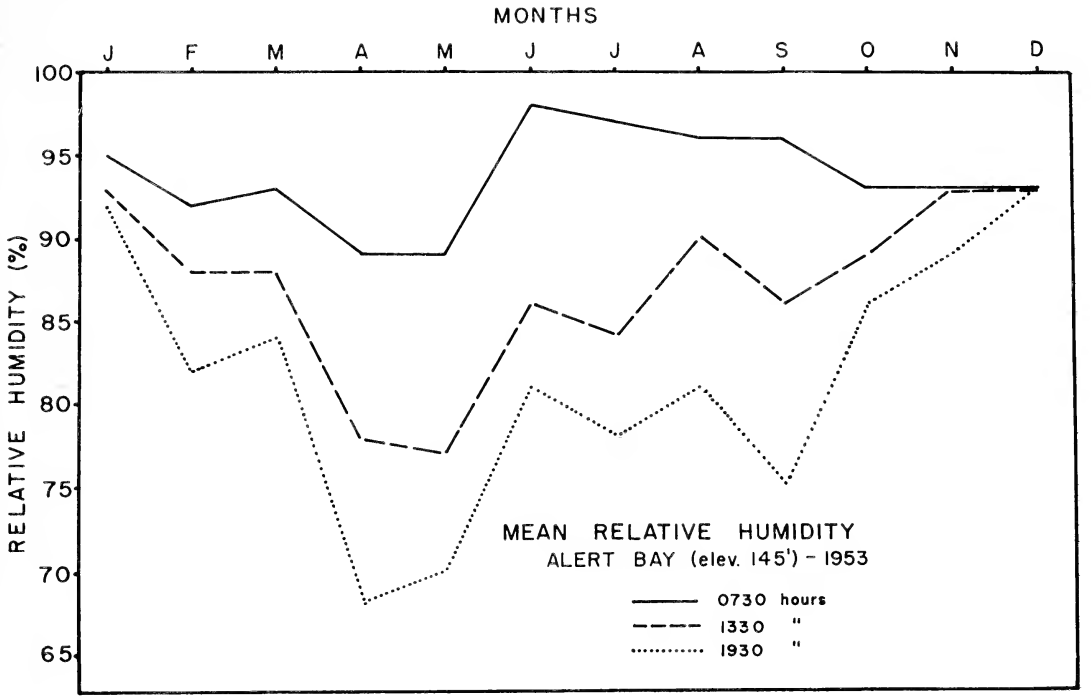

FIG. 31. Monthly relative humidity at Alert Bay, B. C., for 1953.

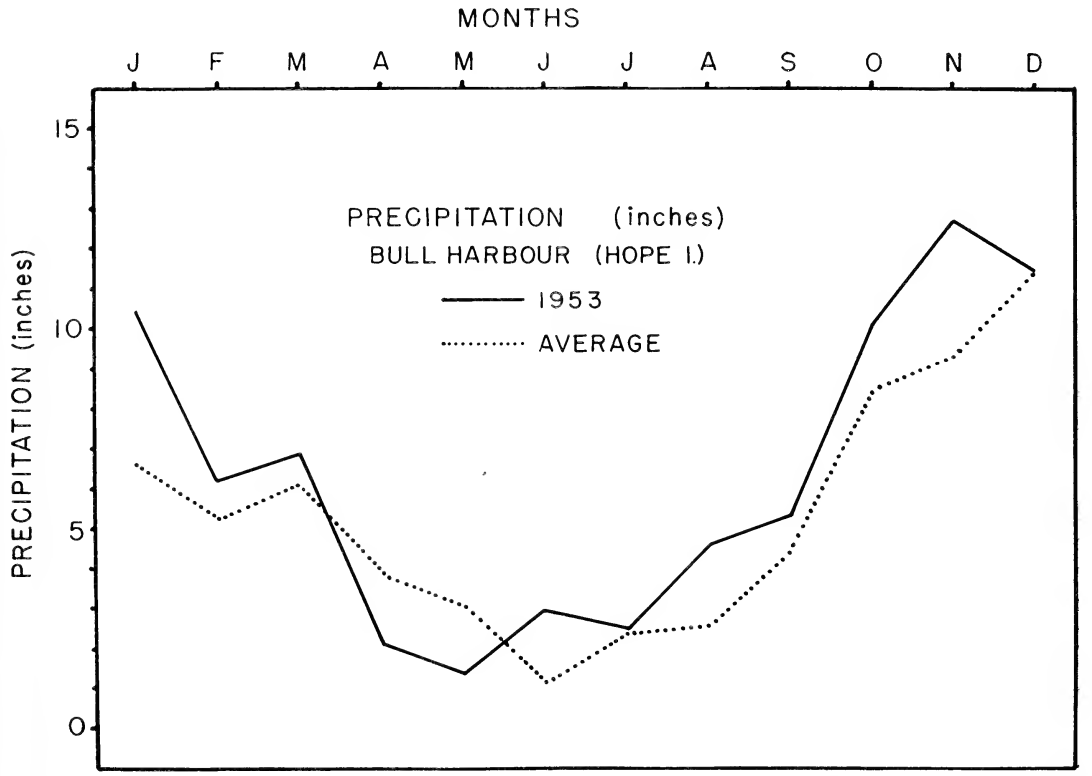

FIG. 32. Monthly precipitation at Bull Harbour, B. C., for 1953.

fluctuations in the central region of the Strait, but for the period available (Fig. 19) a range of from about 5° to 11°C. with an annual mean of 8.25°C. is indicated.

The temperature distribution with depth, as shown by bathythermograph records taken at shallow anchor stations, indicates a well-mixed region near the surface along Vancouver I. and Malcolm I. (Figs. 20–24). Except for slight anomalies the water is generally almost isothermal, with temperatures during this period of observation seldom above 11°C. at the surface and falling to not less than 8°C. at a depth of 20 m. As indicated from the anchor stations, there are no marked changes with time in this general picture of the vertical distribution of temperature, and at any one depth the fluctuations indicated were less than 2 C.° (Figs. 13–17).

However, there is a slight difference (usually not more than 1 C.°) in temperature at the surface at most times of the year, with the water along the Vancouver I. side being warmer than that along the mainland side of the Strait. This is a result of the inflow of colder, less saline water from the mainland inlets.

Seasonal data indicate that in general during the summer months the temperature at the surface is seldom above 10°C. and at a depth of 20 m. is seldom above 9°C. During the winter months it is seldom below 7.5°C. at the surface but may be about 7°C. at a depth of 20 m. This picture of the vertical temperature distribution is somewhat modified during the winter as a result of surface cooling of the water down to a depth of about 20 m. and a temperature inversion has been observed in January which disappears by April. During this early period the water at the depth of 20 m. and, in places, even to a depth of 400 m., may be warmer than that in the upper 20 m. by as much as 1 C.° and

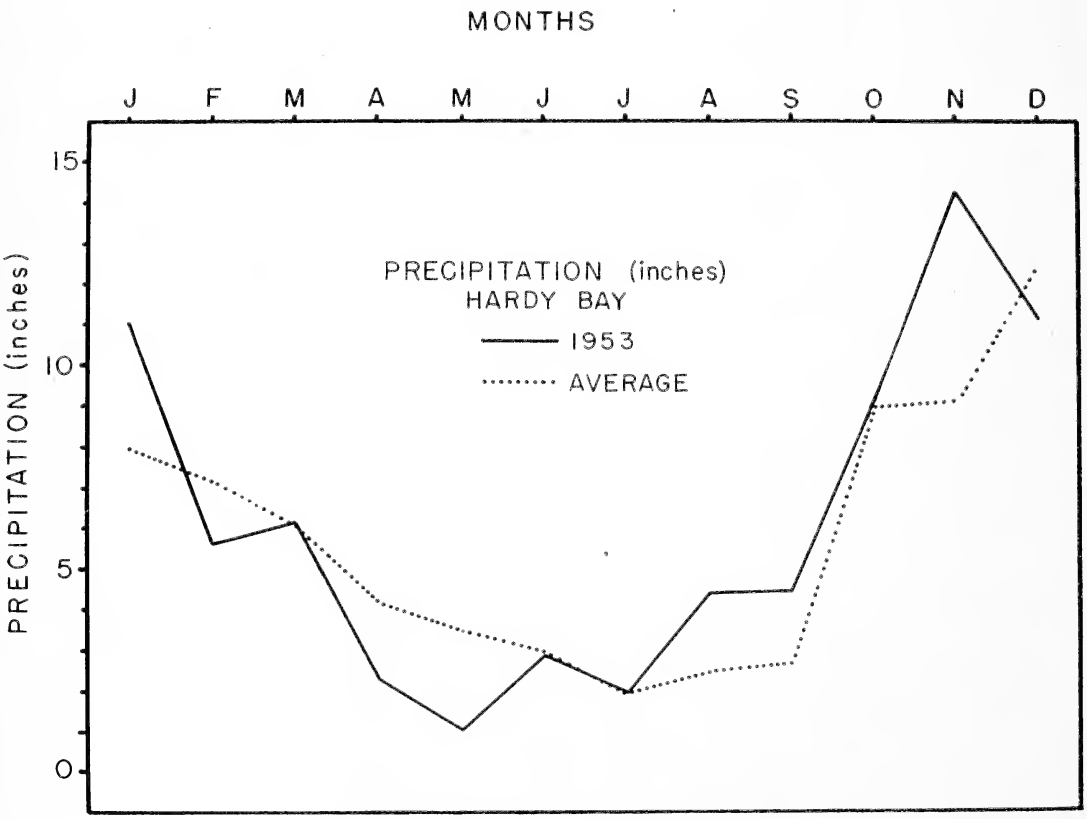

FIG. 33. Monthly precipitation at Hardy Bay, B. C., for 1953.

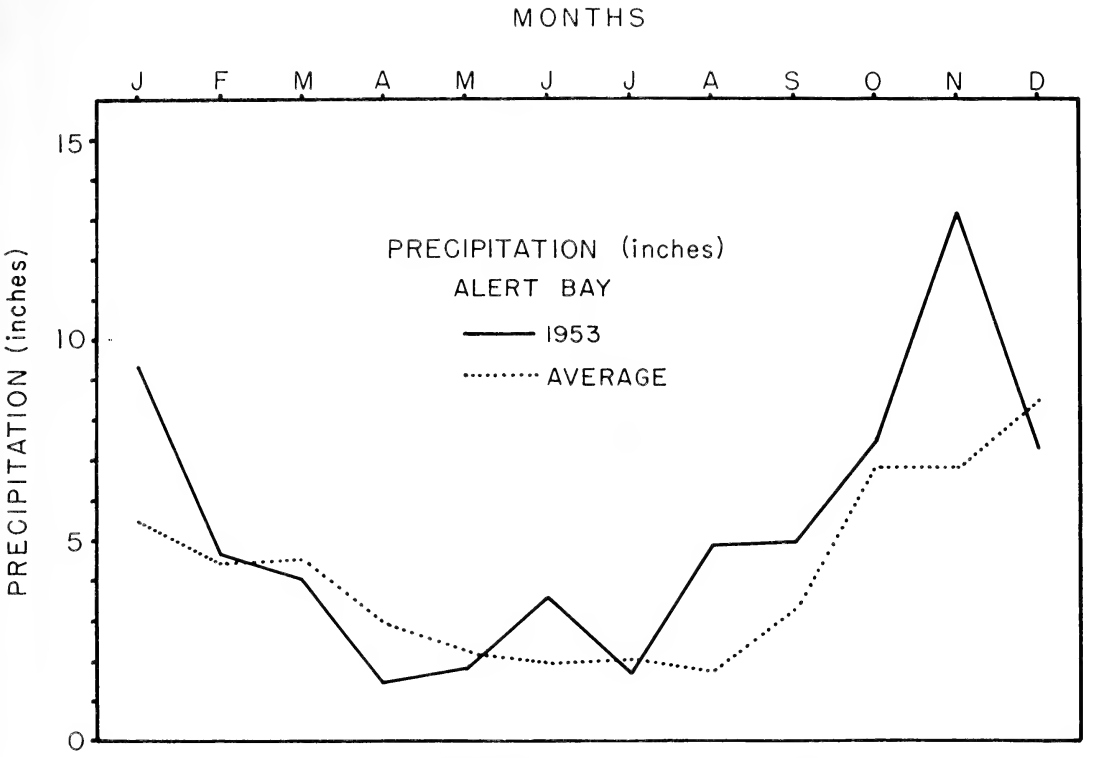

FIG. 34. Monthly precipitation at Alert Bay, B. C., for 1953.

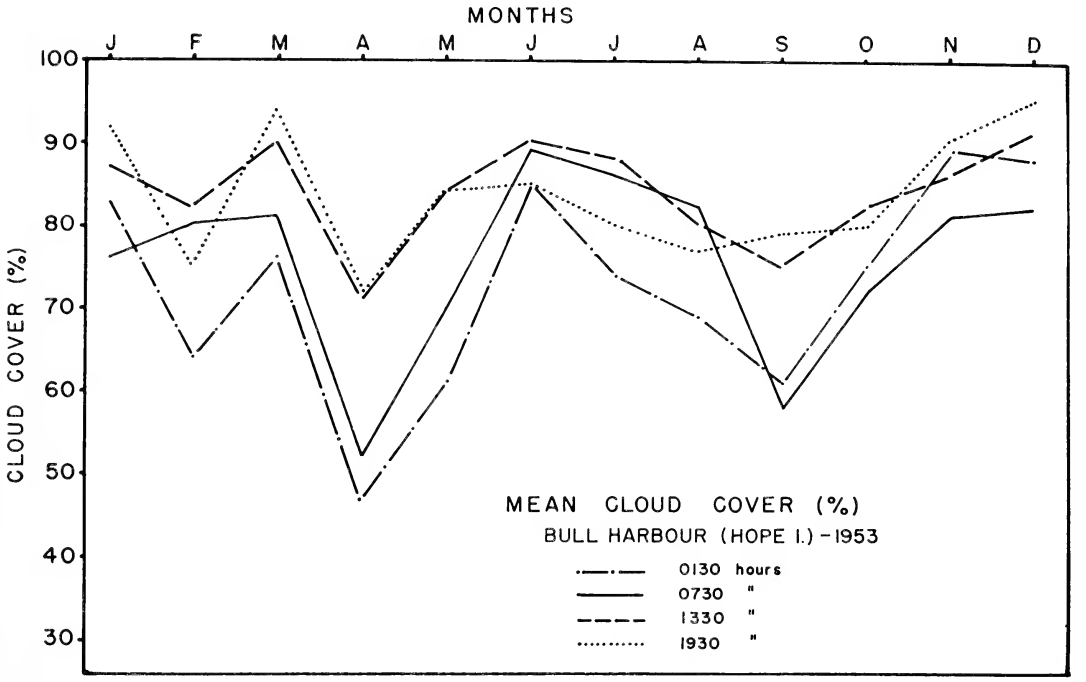

FIG. 35. Monthly cloud cover at Bull Harbour, B. C., for 1953.

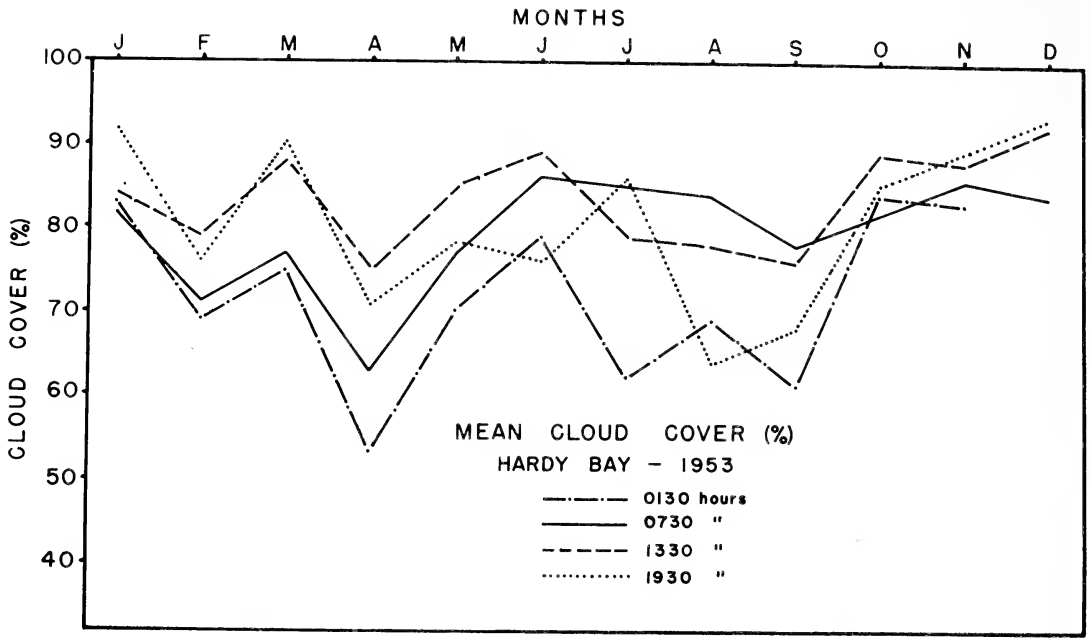

FIG. 36. Monthly cloud cover at Hardy Bay, B. C., for 1953.

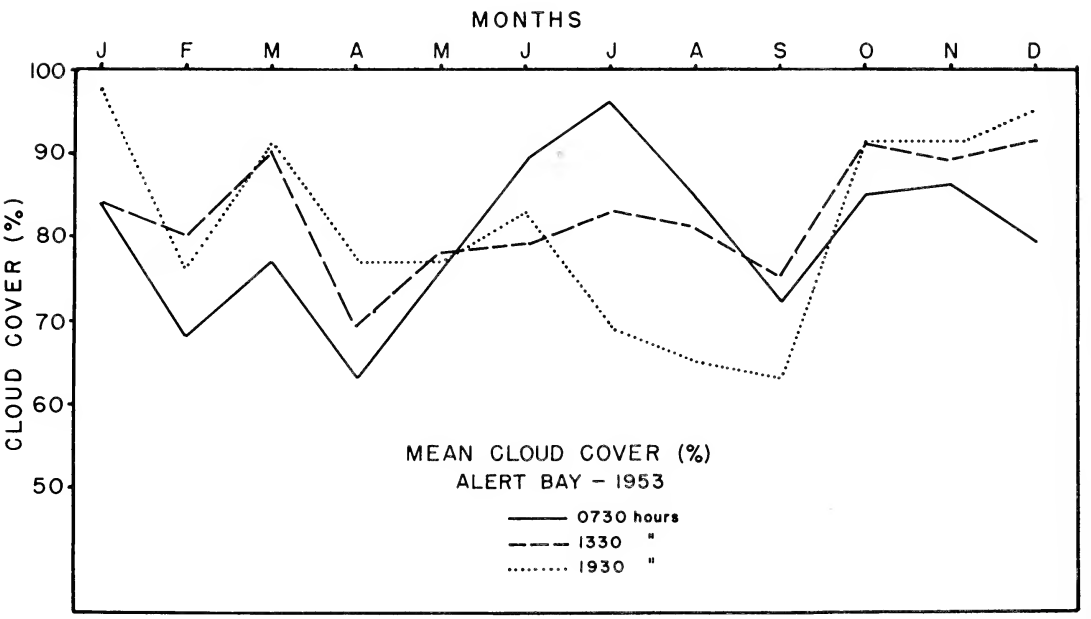

FIG. 37. Monthly cloud cover at Alert Bay, B. C., for 1953.

then fall to a lower temperature again, beneath this warmer upper layer, down to between 6° and 7°C. in the deeper regions.

Thus the environment presented to the intertidal and immediate subtidal zones (see Fig. 25 for terminology) appears to be a relatively stable one as far as the temperature of the seawater is concerned.

Meteorological Conditions

The intertidal region, however, during periods of exposure, is subjected to a varying degree to meteorological conditions, particularly fluctuations in temperature and precipitation, which must be considered in assessing the environment of organisms in this region. A comparison of the meteorological data (air temperatures, precipitation, mean relative humidities, and mean cloud cover) available for the coast of British Columbia, particularly from Bull Harbour (Hope I.), Hardy Bay, and Alert Bay, gives some picture of the meteorological conditions at the northeast end of Vancouver I. (Figs. 26–37).

Along the coast, air from the maritime Pacific Ocean is usually present and results in mild winters and cool summers. Holding a high moisture content, this air does not become extremely hot or cold. However, occasional outbreaks of continental air (polar) from the interior of the

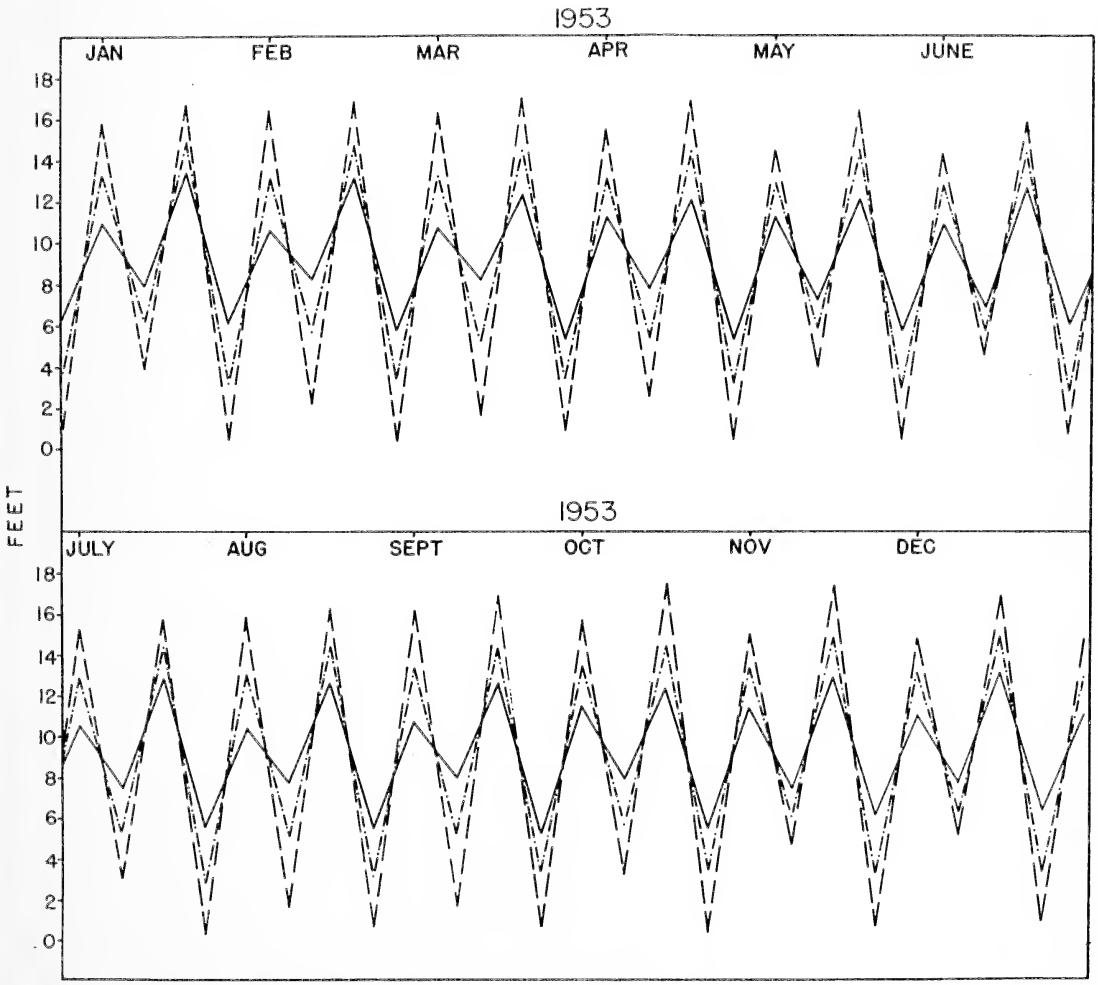

FIG. 38. Monthly summary of tidal features at Hope Island for 1953 (see Figure 39 for significance of lines).

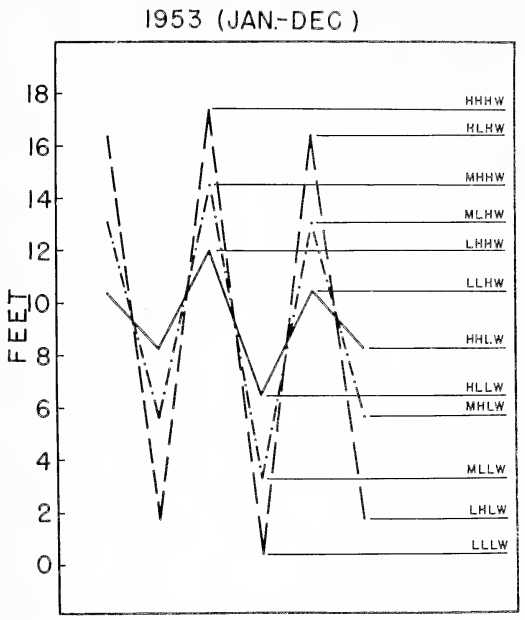

FIG. 39. Summary of tidal features for 1953.

continent bring cold periods during the winter, although generally the Coast and Cascade mountains provide considerable protection. Along the outer coast, the maritime conditions, which are present almost continually, result in high precipitation, prolonged cloudiness, and small ranges in temperature—the typical conditions prevailing in the vicinity of Hope I. (Figs. 26, 29, 32, 35) and Hardy Bay (Figs. 27, 30, 33, 36), despite the fact that these points are somewhat on the lee side of Vancouver I. Along the inner coast and the lee side of Vancouver I., where there is some protection from the maritime influence, precipitation and cloudiness are somewhat reduced and ranges in temperature are somewhat increased, as at Alert Bay (Figs. 28, 31, 34, 37).

The number of frost-free days in the whole Queen Charlotte Strait region averages 200–250 in a year. In both outer and inner regions there are no months with all temperatures ranging below 0°C. In the outer coastal region 4 to 5 months have temperatures above 10°C., and in the inner coastal region 5 to 6 months have temperatures above 10°C. In the outer coastal region, depending upon the locality, the mean monthly air temperatures for January are 1.7° to 4.4°C., and for July 13.3°C., and the mean daily temperatures are —1.1° to 1.7°C. and 15.6° to 18.9°C. for the same months, respectively. In the inner coastal region, depending upon the locality, the mean monthly air temperatures for January are 1.7° to 3.3°C., and for July 15.6° to 18.3°C., and the mean daily temperatures are —1.1° to 0°C. and 21.1° to 23.9°C., respectively, for the same months.

Although some restricted regions of British Columbia on Vancouver I. average as much as 264 in. of rain, in the Queen Charlotte Strait region the annual rainfall averages between 40 and 60 in. at the inner end (including Alert Bay and Malcolm I.), with between 5–10 per cent as snow, and between 60 and 100 in. at the outer end (including Hope I. and Port Hardy), with less than 5 per cent as snow. The period of minimum rainfall is in the summer,

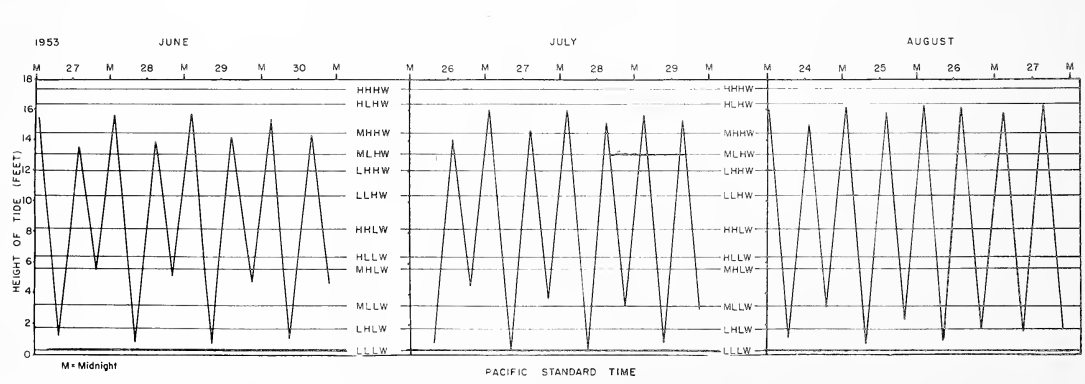

FIG. 40. Tidal features for the periods of greatest exposure during summer months of 1953.

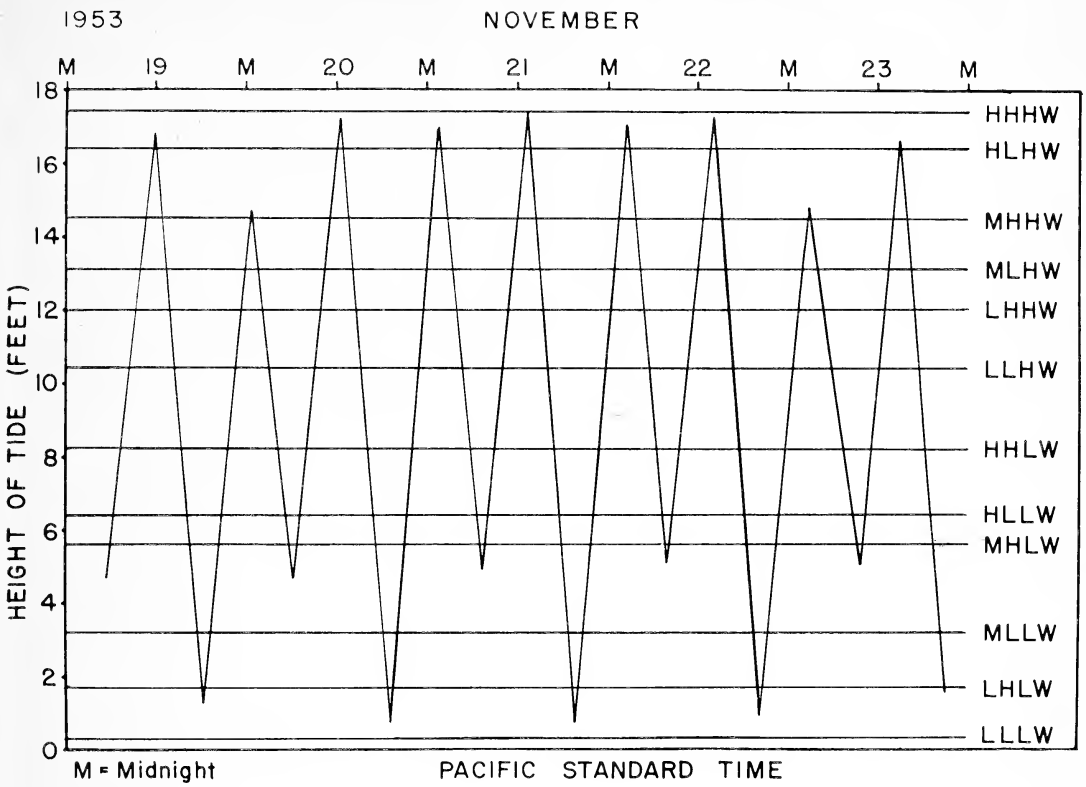

FIG. 41. Tidal features for period of greatest exposure during winter months of 1953.

with between 2–3 in. on the average falling during August in the Strait, and the maximum rainfall occurs in the winter, with between 9–13 in. on the average in December.

Near the entrance of the Strait, especially along the north side of Hope I., conditions of heavy surf generally prevail. Even when there is no sea a heavy swell is common. Farther down in the Strait to the south and east there is an area protected by scattered islands and reefs near the entrance, from the heavy swell from the open ocean, but this whole area is subject to strong westerly winds in the summer months and to even stronger southeasterly winds during the winter months, so that the Strait is generally subjected to strong wave action and wind mixing. During the period mid-September to mid-May the southeasterly winds are predominent and blow at speeds frequently up to 40 m.p.h. and occasionally higher. During the period mid-May to mid-September the westerly winds predominate and blow at speeds up to 25 m.p.h. Particularly during this latter period, however, there may be considerable calm periods, especially during the morning hours, followed by strong seas which reach a peak about 1600 hrs. and then drop rapidly to relative calm by 2000 hrs.

Tidal Characteristics

The tidal amplitude in the vicinity of Hope I. is usually about 17 ft. and the highest on record (37 years) was almost 19 ft. (December, 1941). An extensive intertidal flora and fauna is exposed during low tide periods in this zone. Continuous tidal data are recorded since 1949 at Alert Bay, near station 8 (Fig. 6). At the north end of Vancouver I. the tides are semidiurnal and only moderately declinational, and thus springs and neaps are distinguishable (Figs.

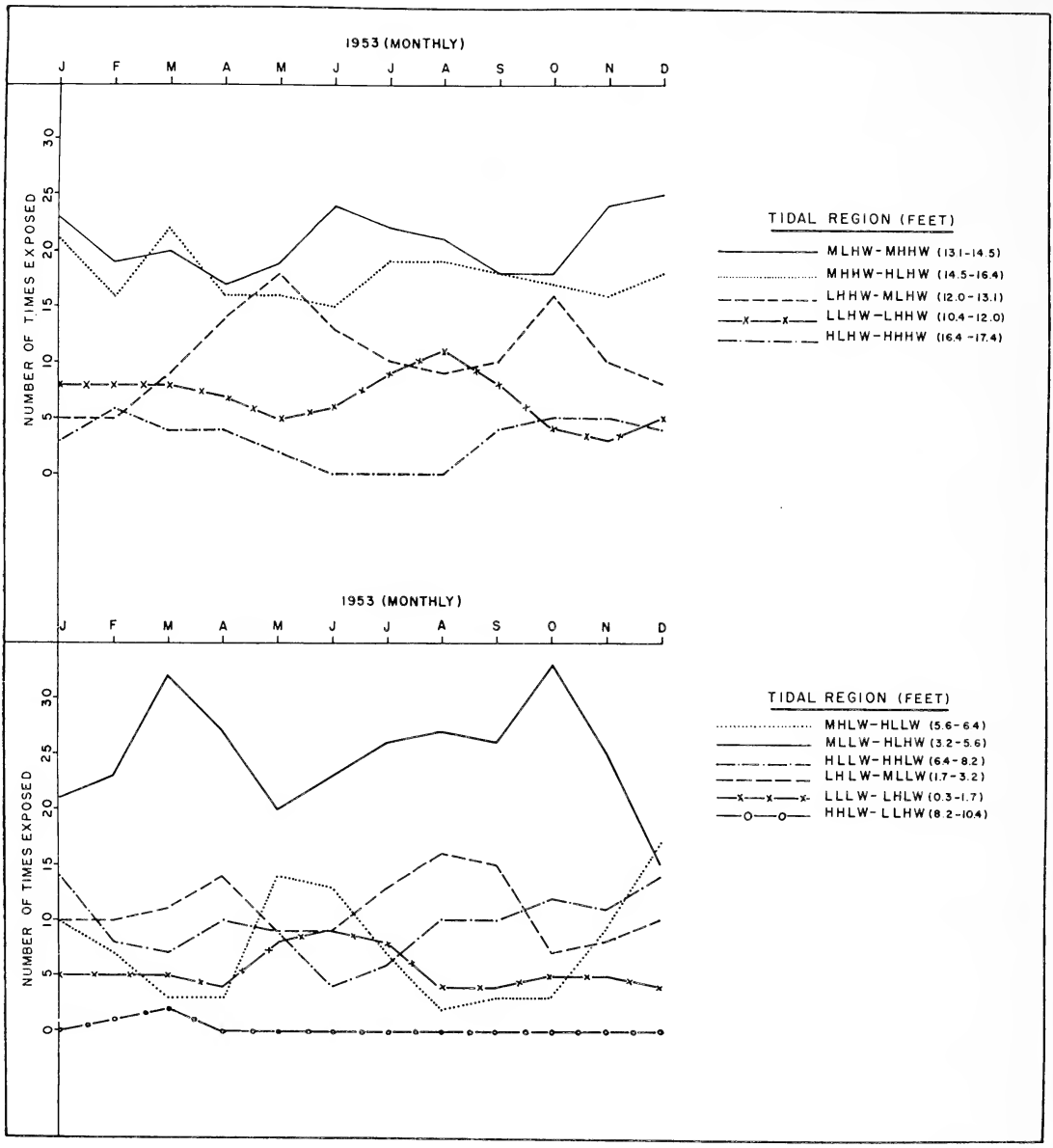

FIG. 42. Diagram showing number of times each month during 1953 various levels in the intertidal zone were exposed.

38–41). Twice a month there are two tides a day which are about equal, and in the intervals between there is a much greater inequality in the height of any two successive low waters than between the two high waters of the same day. During the summer months (Fig. 40) the lowest low waters occur during daylight hours and during the winter months (Fig. 41) the lowest low waters occur late at night or early in the morning.

The number of times during the year when each of the various levels recognized (Fig. 39) are exposed is indicated in Figure 42, and the number of days of continuous exposure of the

upper portions of the intertidal zone are shown in Figure 43. The number of times (and per cent) these levels are exposed (Fig. 44) and submerged (Fig. 45) are also presented in an attempt to indicate possible critical levels. The tide levels are referred to in feet above or below the datum (zero point) which, for the coast of British Columbia, is the level of lowest normal tides.

Chemical Characteristics

During the summer months, when plant production is at its peak in Queen Charlotte Strait, the surface zone may be supersaturated with oxygen; values in excess of 15 mg/l are frequently encountered. The maximum values generally prevailing near the surface and to a depth of 20 m. are between 7 and 10 mg/l. During the summer months the values are somewhat higher than in the winter. The maximum concentration of oxygen occurs at a depth between 2 and 5 m. (Figs. 46, 47), rather than right at the surface during the summer, and is related to the region of maximum phytoplankton activity. The water throughout most of the Strait has a higher oxygen content near the surface (Figs. 46, 47) than in Queen Charlotte Sound or in the adjacent connecting mainland channels. Although marked fluctuations occur locally in the upper 10 m., the general picture is more stable (Figs. 13–17) at greater depth.

Phosphate concentrations (PO_4–P) are not available for the winter months, but for the summer, during which minimum amounts are probably reached, the values present (Fig. 48) were between 0.5 and 2.0 mg.–at. per liter in the upper 20 m. The minima were generally in the upper 10 m. and most of the minima for the Strait and Queen Charlotte Sound were between 1.0 and 1.5 mg.–at. per liter.

BIOLOGICAL CHARACTERISTICS

Biological observations, extending over the length of the coast, indicate that there is a high degree of uniformity in the populations of many benthonic plants and animals extending from the Strait of Juan de Fuca to Dixon Entrance. This would be anticipated under such relatively uniform conditions of temperature. In attempting to correlate the distribution of some of these organisms with salinity characteristics, as well as other oceanographic factors, there are several areas on the coast which could be used for purposes of this study. Although some supporting observations have been made in the Strait of Juan de Fuca and Dixon Entrance, this paper is restricted largely to a consideration of the vicinity of Queen Charlotte Strait near the north end of Vancouver I.

Horizontal Distribution of Organisms in Queen Charlotte Strait

Biological observations have been made throughout the area although a more intensive study and collection has been undertaken at Hope I., Deer I., and in the vicinity of the Keogh River, the Klucksiwi River, and Malcolm I. These areas present a transition from Hope I., where the highest salinities are encountered, to the north and east sides of the Strait, where lowest salinities are found, with Deer I. and Malcolm I. being intermediate between these extremes. The distributions in the Strait of the more conspicuous organisms (Table 1) observed during this study are illustrated in Figure 49. Although both the marine algae and the invertebrate animals have been observed, the emphasis in this study is on the more conspicuous marine algae.

Some organisms in the area are more cos-

FIG. 43. Diagram showing number of days various levels in the intertidal zone were subjected to continuous exposure.

TABLE 1

LIST OF THE MORE CONSPICUOUS SPECIES OF MARINE BENTHONIC ORGANISMS IN QUEEN CHARLOTTE STRAIT

1. *Polyneura latissima* (Harvey) Kylin
2. *Chthamalus dalli* Pilsbry
3. *Tegula funebralis* (Adams)
4. *Acmaea instabilis* (Gould)
5. *Balanus cariosus* (Pallas)
6. *Endocladia muricata* (Harvey) J. Agardh
7. *Gloiopeltis furcata* (Postels et Ruprecht) J. Agardh
8. *Prionitis lanceolata* Harvey
9. *Prionitis lyallii* Harvey
10. *Erythrophyllum delesserioides* J. Agardh
11. *Petrocelis franciscana* Setchell et Gardner
12. *Hildenbrandia occidentalis* Setchell
13. *Opuntiella californica* (Farlow) Kylin
14. *Plocamium pacificum* Kylin
15. *Gigartina papillata* (C. Agardh) J. G. Agardh
16. *Gigartina sitchensis* Ruprecht
17. *Iridaea cordata* (Turner) Bory
18. *Iridaea heterocarpa* Postels et Ruprecht
19. *Halosaccion glandiforme* (Gmelin) Ruprecht
20. *Rhodymenia palmata* (Linnaeus) Greville f. *palmata*
21. *Gastroclonium coulteri* (Harvey) Kylin
22. *Microcladia borealis* Ruprecht
23. *Ptilota asplenioides* (Esper) C. Agardh
24. *Ptilota californica* Ruprecht
25. *Ptilota hypnoides* Harvey
26. *Hymenena setchellii* Gardner
27. *Hymenena flabelligera* (J. Agardh) Kylin
28. *Cryptopleura ruprechtiana* (J. Agardh) Kylin
29. *Polysiphonia collinsii* Hollenberg var. *collinsii*
30. *Pterosiphonia bipinnata* (Postels et Ruprecht) Falkenberg var. *bipinnata*
31. *Laurencia spectabilis* Postels et Ruprecht
32. *Rhodomela larix* (Turner) C. Agardh
33. *Odonthalia floccosa* (Esper) Falkenberg
34. *Odonthalia washingtoniensis* Kylin
35. *Prasiola meridionalis* Setchell et Gardner
36. *Agardhiella coulteri* (Harvey) Setchell
37. *Saundersella simplex* (Saunders) Kylin
38. *Heterochordaria abietina* (Ruprecht) Setchell et Gardner
39. *Desmarestia intermedia* Postels et Ruprecht
40. *Desmarestia herbacea* Lamouroux
41. *Desmarestia media* var. *tenuis* Setchell et Gardner
42. *Desmarestia munda* Setchell et Gardner
43. *Soranthera ulvoidea* Postels et Ruprecht f. *ulvoidea*
44. *Myelophycus intestinale* Saunders
45. *Scytosiphon lomentaria* (Lyngbye) J. Agardh f. *lomentaria*
46. *Coilodesme bulligera* Stroemfelt
47. *Laminaria cuneifolia* J. Agardh f. *cuneifolia*
48. *Laminaria saccharina* (Linnaeus) Lamouroux f. *saccharina*
49. *Laminaria setchellii* Silva
50. *Pleurophycus gardneri* Setchell et Saunders
51. *Agarum fimbriatum* Harvey
52. *Agarum cribrosum* Bory
53. *Hedophyllum sessile* (C. Agardh) Setchell
    a. smooth form
    b. bullate form
54. *Postelsia palmaeformis* Ruprecht
55. *Lessoniopsis littoralis* (Farlow et Setchell) Reinke
56. *Pterygophora californica* Ruprecht
57. *Egregia menziesii* (Turner) Areschoug subsp. *menziesii*
58. *Fucus evanescens* C. Agardh f. *evanescens*
59. *Fucus gardneri* Silva f. *gardneri*
60. *Pelvetiopsis limitata* (Setchell) Gardner f. *limitata*
61. *Cystoseira geminata* C. Agardh
62. *Smithora naiadum* (Anderson) Hollenberg
63. *Porphyra perforata* J. Agardh f. *perforata*
64. *Farlowia mollis* (Harvey et Bailey) Farlow et *Setchell*
65. *Dilsea californica* (J. Agardh) O. Kuntze
66. *Gloiosiphonia californica* (Farlow) J. Agardh
67. *Nereocystis luetkeana* (Mertens) Postels et Ruprecht
68. *Macrocystis integrifolia* Bory
69. *Alaria nana* Schrader
70. *Alaria marginata* Postels et Ruprecht
71. *Alaria tenuifolia* Setchell f. *tenuifolia*
72. *Alaria valida* Kjellman et Setchell f. *valida*
73. *Bangia fuscopurpurea* (Dillwyn) Lyngbye
74. *Bossiella plumosa* (Manza) Silva
75. *Bossiella californica* (Decaisne) Silva
76. *Calliarthron regenerans* Manza
77. *Calliarthron schmittii* Manza
78. *Callithamnion pikeanum* Harvey var. *pikeanum*
79. *Callophyllis edentata* Kylin
80. *Callophyllis firma* Kylin
81. *Cladophora trichotoma* (C. Agardh) Kützing
82. *Spongomorpha coalita* (Ruprecht) Collins
83. *Codium fragile* (Suringar) Hariot
84. *Codium setchellii* Gardner
85. *Coilodesme californica* (Ruprecht) Kjellman
86. *Constantinea simplex* Setchell
87. *Constantinea subulifera* Setchell
88. *Corallina officinalis* var. *chilensis* (Harvey) Kützing
89. *Costaria costata* (Turner) Saunders
90. *Costaria mertensii* J. Agardh
91. *Cryptosiphonia woodii* J. Agardh
92. *Cumagloia andersonii* (Farlow) Setchell et Gardner
93. *Cymathere triplicata* (Postels et Ruprecht) J. Agardh
94. *Halicystis ovalis* (Lyngbye) Areschoug
95. *Pylaiella litoralis* (Lyngbye) Kjellman
96. *Leathesia difformis* (Linnaeus) Areschoug
97. *Haplogloia andersonii* (Farlow) Levring

TABLE 1 *(continued)*

98. *Ahnfeltia concinna* J. Agardh
99. *Rhodoglossum latissimum* J. Agardh
100. *Iridaea lineare* (Setchell et Gardner) Kylin
101. *Ahnfeltia plicata* (Hudson) Fries
102. *Schizymenia pacifica* Kylin
103. *Rhodoglossum affine* (Harvey) Kylin
104. *Flustrella corniculata* (Smitt)
105. *Mytilus californianus* Conrad
106. *Mitella polymerus* (Sowerby)
107. *Pisaster ochraceus* (Brandt)
108. *Balanus glandulus* (Darwin)
109. *Styela montereyensis* (Dall)
110. *Haliotis kamtschatkana* Jones
111. *Strongylocentrotus drobachiensis* (Müller)
112. *Strongylocentrotus purpuratus* (Stimpson)
113. *Strongylocentrotus franciscanus* (Agassiz)
114. *Mytilus edulis* Linnaeus
115. *Littorina planaxis* Phillippi
116. *Dictyoneurum californicum* Ruprecht
117. *Phyllospadix scouleri* Hooker
118. *Zostera marina* L. var. *marina*
119. *Balanus nubilus* Darwin
120. *Ulva latissima* L.
121. *Rhizoclonium riparium* (Roth) Harvey
122. *Porphyrella gardneri* Smith et Hollenberg
123. *Desmarestia ligulata* (Lightfoot) Lamouroux
124. *Amplisiphonia pacifica* Hollenberg
125. *Rhodymenia pertusa* (Postels et Ruprecht) J. Agardh
126. *Pterochondria woodii* (Harvey) Hollenberg

mopolitan in their distribution, particularly in their tolerance to extreme dilution. Extending throughout the Strait (Fig. 49) are forms such as *Alaria tenuifolia* Setchell f. *tenuifolia, Cymathere triplicata* (P. and R.) J. Ag., *Costaria costata* (Turn.) Saunders, *C. mertensii* J. Ag., *Laminaria saccharina* (L.) Lamour. f. *saccharina, Nereocystis luetkeana* (Mert.) P. and R., *Porphyra perforata* J. Ag. f. *perforata, Rhodomela larix* (Turn.) C. Ag., *Odonthalia floccosa* (Esper) Falk., *Mytilus edulis* Linnaeus, *Littorina planaxis* Philippi, and *Strongylocentrotus drobachiensis* (Müller).

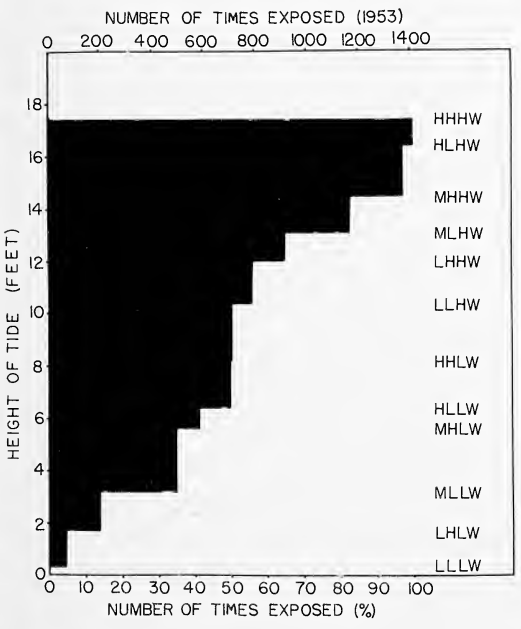

FIG. 44. Diagram showing number (and per cent) of times tidal condition caused exposure of various regions in the intertidal zone.

Restricted to the region of highest salinity, as at Hope I., are *Postelsia palmaeformis* Rupr., *Lessoniopsis littoralis* (Farl. and Setch.) Reinke, *Laminaria setchellii* Silva, *Pelvetiopsis limitata* (Setchell) Gardner f. *limitata, Dilsea californica* (J. Ag.) O. Kuntze, *Erythrophyllum delesserioides* J. Ag., *Iridaea lineare* (S. and G.) Kylin, *Hymenena setchellii* Gardner, *Ptilota asplenioides* (Esper) C. Ag., *P. californica* Rupr., *P. hypnoides* Harvey, *Mitella polymerus* (Sowerby), and *Flustrella corniculata* (Smitt).

A smooth form of *Hedophyllum sessile* (C. Ag.) Setch., *Pleurophycus gardneri* Setch. and Gardner, and *Styela montereyensis* Dall are also present in regions of highest salinity, but are somewhat less restricted in their distribution and extend into the Strait as far as Deer I.

A few organisms extend still farther into the Strait but only slightly beyond Deer I. Among these are *Alaria nana* Schrader and *A. marginata* P. and R. Still others extend from Hope I. throughout the Deer I. region and as far as Malcolm I., but not as far as the east and north sides of the Strait. Among these are *Mytilus californianus* Conrad, *Strongylocentrotus purpuratus* (Stimpson), *Macrocystis integrifolia* Bory, *Egregia menziesii* (Turner) Aresch. subsp. *menziesii*, the typical bullate form of *Hedophyllum sessile* (C. Ag.) Setch., *Alaria valida*

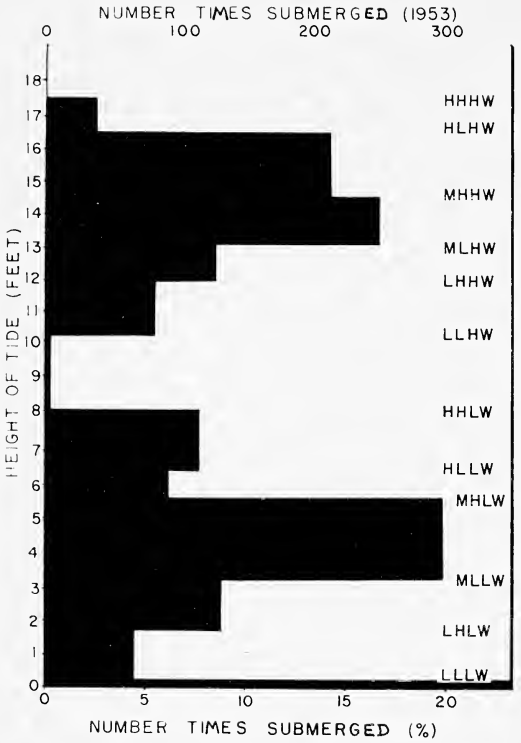

FIG. 45. Diagram showing number (and per cent) of times tidal condition caused submergence of various regions in the intertidal zone.

(Kjellm. and Setch.) f. *valida, Constantinea simplex* Setch., and *Haliotis kamtschatkana* Jones. Isolated populations of the abalone (*Haliotis kamtchatkana*), which have been noted farther eastward in Johnstone Strait and which may be related to local oceanographic features, present something of an anomaly in the general distribution. An exception to the general distribution described in this group is that of *Macrocystis integrifolia.* Although *Macrocystis* occurs in regions of high salinity and extends as far down the Strait as the north side of Malcolm I. and the south side of Numas I., it does not occur in the most exposed areas where *Postelsia* and *Mitella* are encountered.

Vertical Distribution of Organisms

The vertical distributions with reference to tide levels, based on data obtained using an Abney level, are presented for some of the more conspicuous organisms at Hope I. (Fig. 50). Comparisons are made also for some of these (Fig. 51) at Hope I., Deer I., and near the Klucksiwi River, to indicate the effect exposure to surf has on the vertical distribution of some organisms.

By comparing the vertical distributions of organisms in Queen Charlotte Strait (Fig. 50) with tidal data presented with respect to emergence and submergence (Figs. 42–45), a number of limiting levels are fairly apparent. Near the top of the intertidal zone is a region (HHHW to HLHW) which is rarely submerged (Fig. 43) for more than a few hours on each of a few days at any period of the year and which

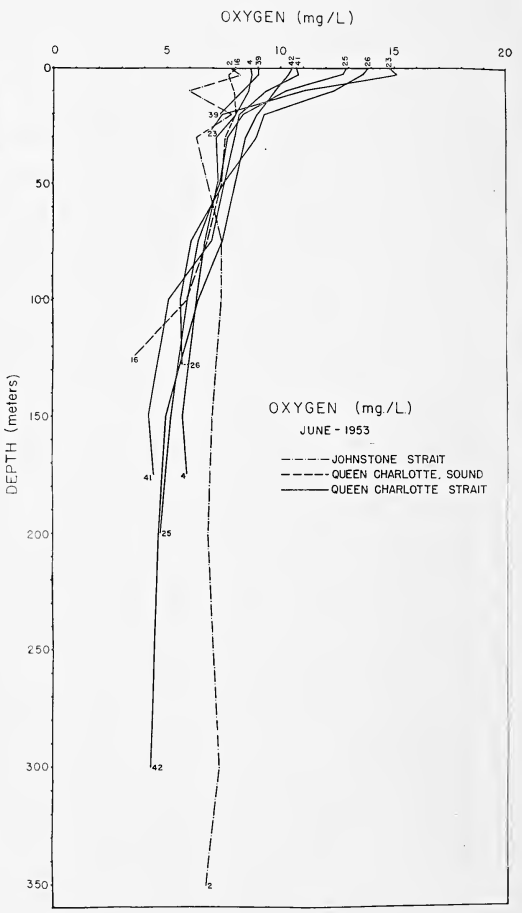

FIG. 46. Distribution of oxygen with depth at various stations in Queen Charlotte Strait and adjacent regions in June, 1953.

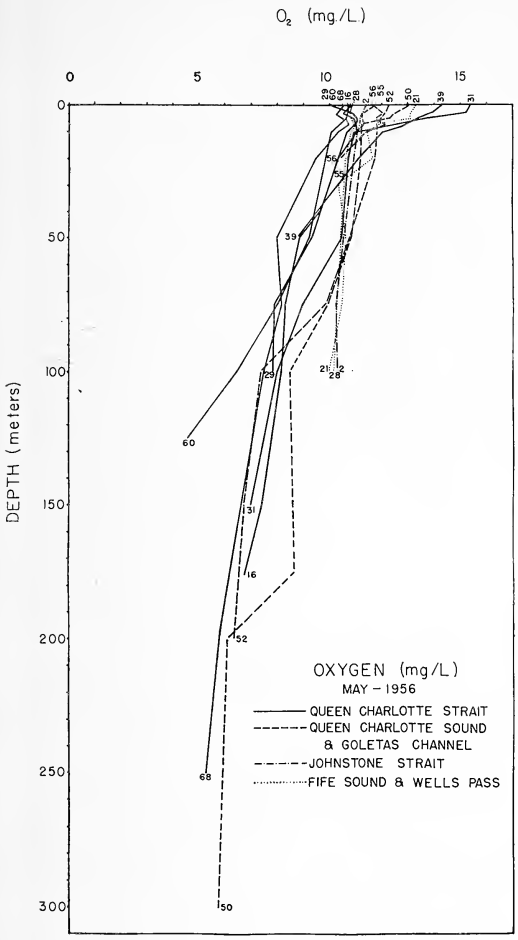

FIG. 47. Distribution of oxygen with depth at various stations in Queen Charlotte Strait and adjacent regions in May, 1956.

may be continuously exposed for as long as 4 months during the summer period. Those organisms that can tolerate such conditions are rare and in this zone one finds chiefly *Littorina,* which is capable of moving sufficiently to extend into lower less extreme zones when necessary. In the region below (HLHW to MHHW), continuous exposure to the air may last for periods ranging from a few days to almost 2 weeks, and these periods occur at least twice a month, but the rest of the time this zone is submerged at least once a day. In the region below (MHHW to MLHW), continuous exposure to the air is rarely for more than a few days at a time, and for a few months during the winter the region is submerged at least once a day. Although the upper limit of a number of the organisms (Fig. 50) in this region of the intertidal zone between 13.1 and 17.4 ft. varies to some extent with the organism, it is apparent that in this general region an upper boundary is probably determined directly or indirectly by the degree of exposure to climatic conditions. The precise tide level, if there is one, at which this boundary occurs is not clear from the data available. The effect of surf in the exposed environment may also cause some variation in the upper limit of the vertical distribution. Since the greatest change in degree of exposure within this upper region (13.1–17.4 ft.) occurs between MLHW and MHHW, a critical level is suggested at this point for a considerable number of conspicuous organisms.

All portions of the intertidal zone below MLHW are submerged at least once a day for various periods. The greatest change in conditions of submergence (Fig. 45) in the region of the middle intertidal zone (8.2–13.1 ft.) occurs between HHLW and LLHW, and it is at this point where another critical level is suggested, in some instances as the upper limit and in others as near the lower limit of the vertical distribution of certain organisms (Fig. 50).

In the lower intertidal zone (0–8.2 ft.) the most extreme change in conditions of exposure (Fig. 44) and submergence (Fig. 45) occurs between MLLW and MHLW, and this is again reflected both at the upper and lower limits in the vertical distribution of certain organisms (Fig. 50). Another critical level (Fig. 50) occurs in the region between LLLW and LHLW, where another region of marked change (Fig. 45) exists in conditions of submergence.

Although the upper limits in most instances appear to be relatively sharp, there is less consistency in this respect concerning lower limits. This suggests that other factors, perhaps competition for space or predation, may be responsible for limiting distribution, particularly downward in some instances.

DISCUSSION

Knowing as we do from experimental work the responses of some organisms to environmental factors, it seems reasonable to anticipate

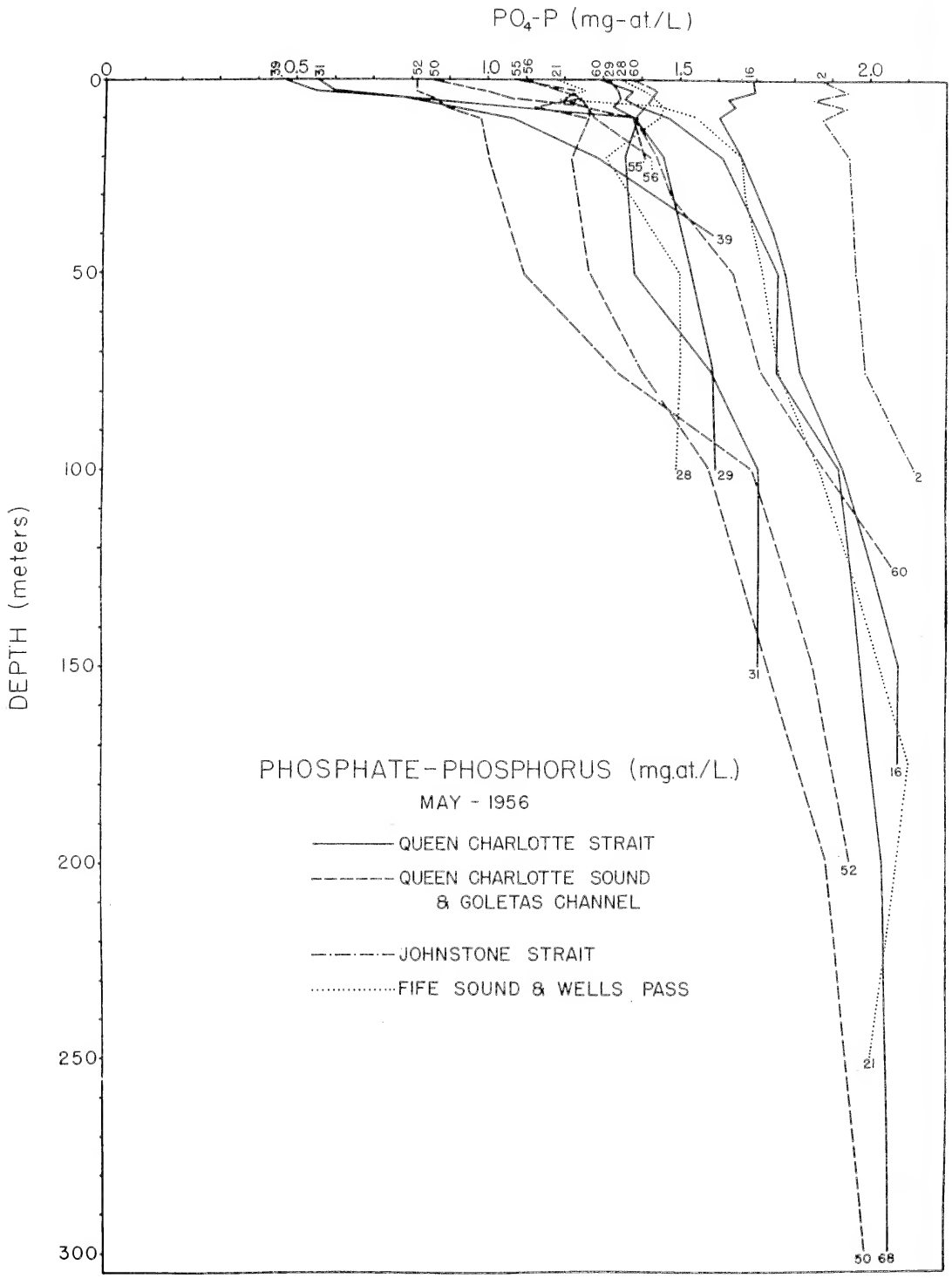

FIG. 48. Distribution with depth of phosphate-phosphorous at various stations in Queen Charlotte Strait and adjacent regions in May, 1956.

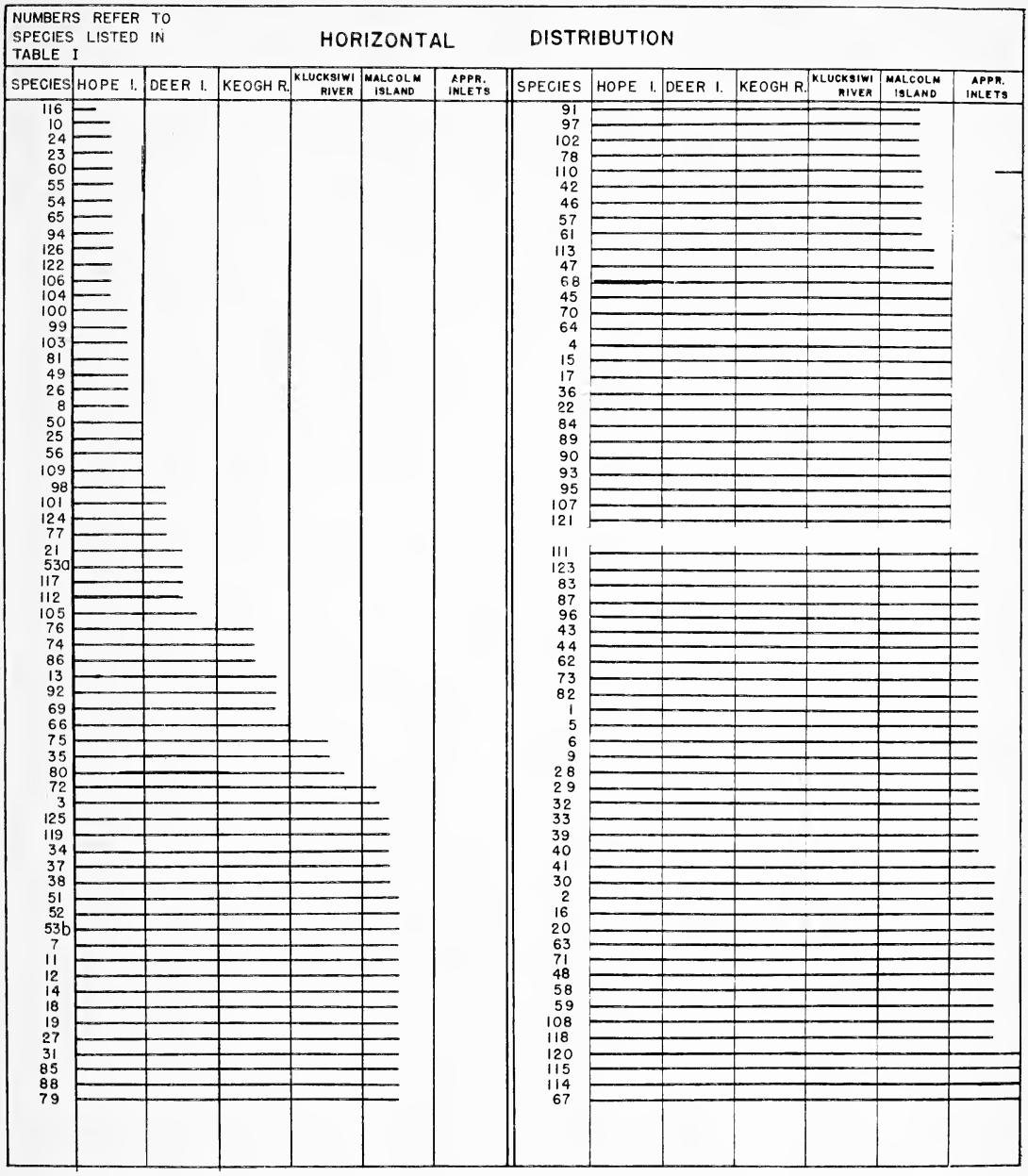

FIG. 49. Horizontal distribution of marine benthonic organisms in Queen Charlotte Strait.

that the distribution of marine organisms in time and space can be explained on the basis of oceanographic features—provided the geological, physical, chemical, and biological factors of the environment and their interaction can be adequately assessed. Any attempt to oversimplify such a many-sided and complicated study would be an avoidance of reality. However, in such a study one expects to make assumptions based on the knowledge available, in some instances of necessity by extrapolation, and to pass through a descriptive phase in an attempt to

correlate observed distributions on the basis of and in relation to other factors in the environment. These comparisons may be largely qualitative in the first instance, but the intent is that they be not only qualitative but also quantitative in the final analysis and, as in all branches of science, eventually permit predictions. At best, however, only a descriptive treatment can be attempted at this point and can only point the way to further studies and hypotheses.

There have been many attempts to describe the zonation of marine organisms on the shore, and a great jumble of appalling confusion in ecological terminology has evolved to the point where some magic significance is sometimes associated with the terms and units involved. Although the need for this descriptive phase of the study (with a minimum of terminology) is recognized at an early stage of study or in a new area under investigation, once it has served

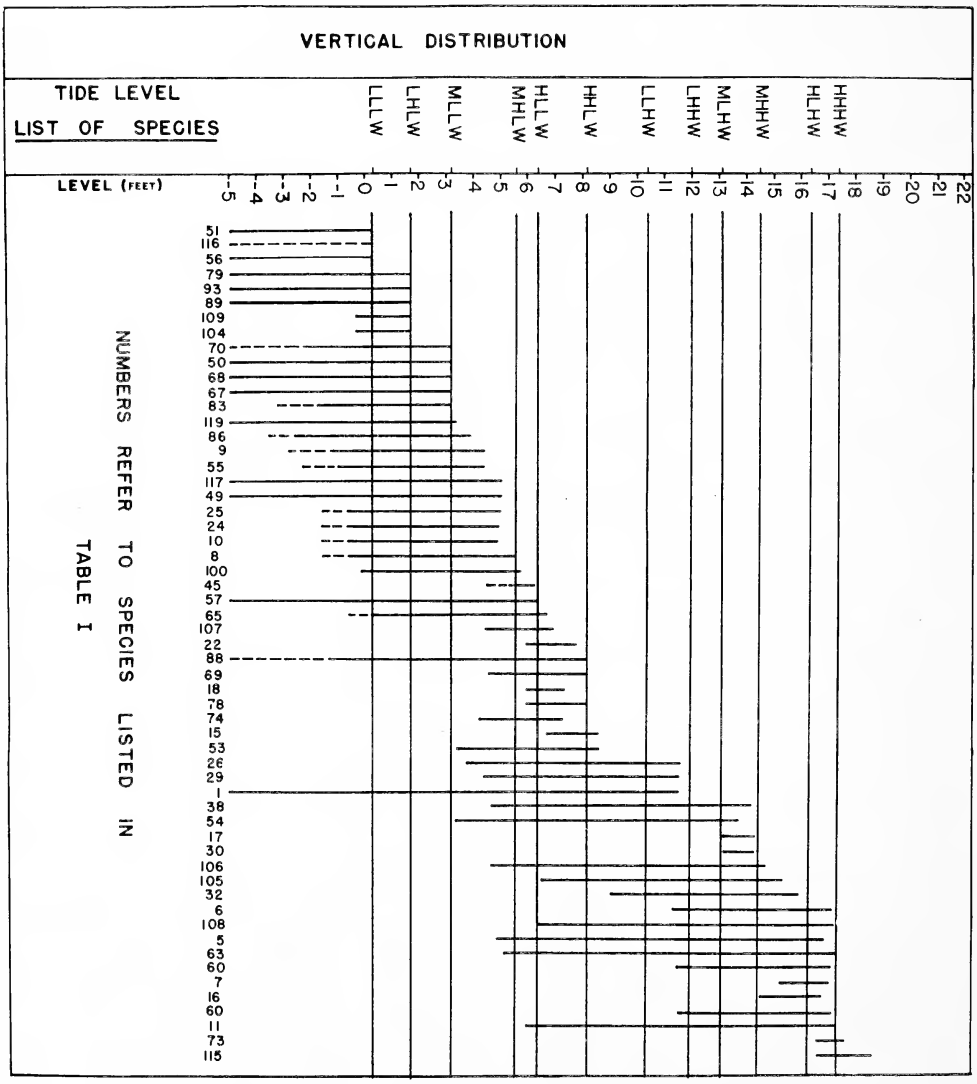

FIG. 50. Vertical distribution of some marine benthonic organisms at Hope Island.

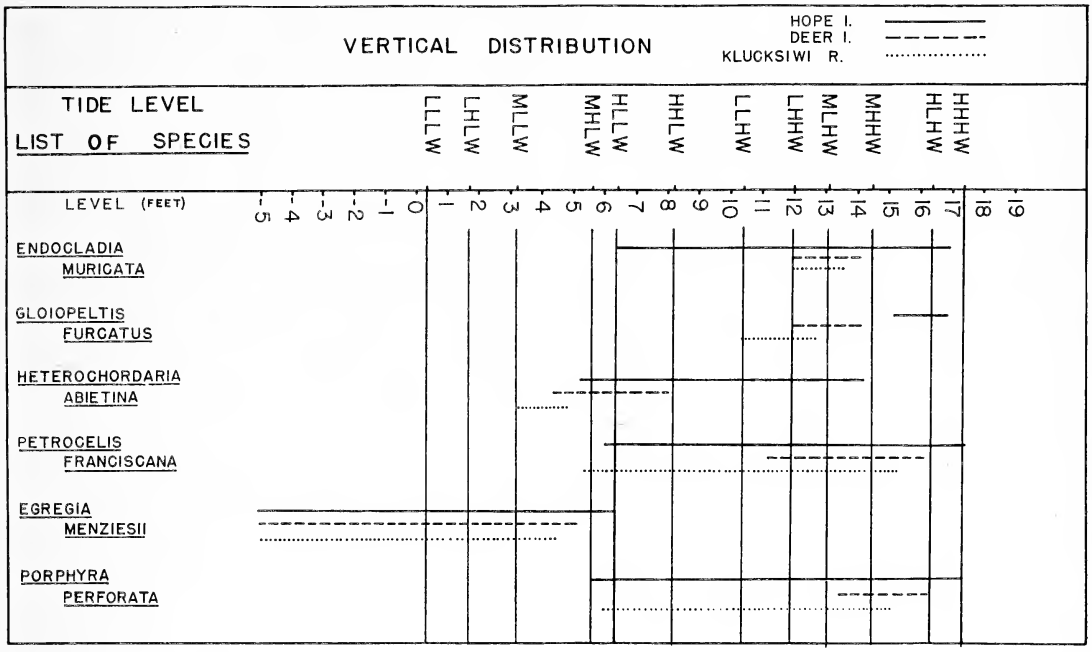

FIG. 51. Comparison of vertical distribution of some benthonic organisms at several points in Queen Charlotte Strait.

its initial purpose little refinement in this method of approach seems conducive to an explanation of the causal factors. From this point it becomes necessary to look at the problem from a new perspective involving a detailed study of the organisms concerned—an understanding of their life histories, rate of growth, reproduction, and various physiological requirements and tolerances in relation to the environment. These problems may be and, as already indicated, have been approached to some extent by actual field studies and experiments as well as by laboratory studies under controlled conditions.

It is with this philosophy in mind that this study has been approached to the extent possible from the existing data, initially from the standpoint of the oceanographer with an analysis of the environmental factors and their relation to the organisms. The success of these preliminary efforts both in the field as well as in the laboratory supports the conviction that the approach is a useful and instructive one. Differences which sometimes appear striking or significant on a broad scale are frequently less apparent and confused in a local area. The distribution of the genus *Macrocystis* is an interesting case in point. Although the global pattern of distribution of this genus is rather clearly established (Setchell, 1932; Womersley, 1954) on the basis of temperature distributions and hence follows the pattern of distribution of some of the cold water currents of both southern and northern hemispheres, the distribution of *M. integrifolia* in British Columbia follows a distinct salinity distribution. As yet, however, it cannot be conclusively stated in the latter instance that salinity itself is the causal factor. It still remains to be established whether salinity in terms of an osmotic relationship, or some parallel factor associated with open ocean water of high salinity, provides a causal mechanism for the distribution of *M. integrifolia* on this coast.

It is clear that there is a horizontal distribution of organisms, including *Macrocystis integrifolia,* in Queen Charlotte Strait which follows closely the pattern of salinity distribution in the

Strait. In turn this reflects the circulation within the area. It would be premature to say that salinity is directly responsible for the observed distributions of all the organisms encountered. But one may say that the distribution reflects the dependence on high salinity water which is characteristic of the open ocean and exposure. In some instances it may be salinity that is a direct causal factor. On the other hand, the open coast has organisms associated with surf conditions. It has been suggested that the high oxygen requirement of certain organisms is met only in such an exposed environment. However, the distributions and concentrations of oxygen in the sea in this area do not directly support this argument. The oxygen content of the waters within the sheltered Strait is as high or higher than in the surf in the exposed regions. This is particularly true in the central part of the Strait when there is a heavy bloom of phytoplankton, at which time the water may be supersaturated with oxygen to as much as 175 per cent. Likewise, although it is known that many marine algae have a high inorganic phosphate requirement, there is no evidence that this nutrient is ever limiting in this area within the zone occupied by the benthonic algae. There is a great need for further knowledge of the presence, distribution, amounts, and availability of many more dissolved inorganic as well as organic substances and perhaps even of growth substances. There is also need for a study of the quantitative aspects of removal, the rate of removal of such substances, and precise requirements for growth and reproduction in the micro-environment of the marine benthonic algae. The restriction of certain organisms to surf conditions suggests that constant movement of water is required to provide nutrients and gases which may be rapidly exhausted from the immediate or micro-environment of the individual fixed alga, or in the case of the sessile marine invertebrates, such as *Mitella polymerus,* to provide particulate food. It may be that lowering the concentration or removal by dilution or by water movement of some toxic substances which may accumulate above a certain concentration in the micro-environment is just as significant as the availability of others.

SUMMARY

A detailed study of the horizontal and vertical distributions of marine benthonic organisms in Queen Charlotte Strait has been limited so far to the more conspicuous algae and invertebrates encountered. The relationship of these distributions to the salinity distribution indicates that more intensive study of the flora and fauna in this area, as well as elsewhere on the coast, will provide further supporting evidence indicating not only the effect of oceanographic variables on the distribution and production of marine benthonic organisms but also the possibility of using such organisms as indicators of oceanographic conditions both in time and space. The relationship of the vertical distribution of some of the organisms to certain tide levels indicates the response of the different organisms to varying degrees of exposure and submergence.

This oceanographic approach, both qualitatively and quantitatively, has given a broad understanding of some of the possible factors which are likely to be responsible for the observed distributions. However, before there can be a clear understanding and explanation of the fundamental relationships between the organisms and their environment in this region, as well as an understanding of the interrelationships and interaction among the organisms themselves, additional field observations, field experiments, and laboratory experiments must be undertaken.

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Description of a New Species of *Pranesus* (Atherinidae: Pisces) from the Capricorn Group, Great Barrier Reef

D. J. WOODLAND[1]

DURING 1956–7 Richard J. Slack-Smith, Department of Zoology, University of Queensland, and the author investigated the fish fauna of Heron Island, Capricorn Group. A check list of the recorded species is to be published conjointly (Pap. Dep. Zool. Univ. Qd.). The fish described here is one of a number of new species collected at the island.

SUBFAMILY TAENIOMEMBRADINAE Schultz

GENUS *Pranesus* Whitley

Pranesus capricornensis, sp. nov.

HOLOTYPE: 93 mm. standard length, from reef flat, Heron I., Aug. 1956, collected by R. J. Slack-Smith, Queensland Museum no. I/8201.

PARATYPES: Queensland Museum nos. I/8202–5; 4 specimens, 69, 78, 85, and 88 mm.; 85 and 88 mm. fish taken along with holotype, 69 and 78 mm. fish collected by Woodland, Mar. 1957, reef flat, Heron I.

DESCRIPTION: Dorsal rays VII (V–VII) I,i,8 (9); anal I,i,12 (to 14); pectoral I,i,15; ventral I,5; caudal i,8 + 7,i. Scales from upper limit of gill opening to root of caudal fin 47 (46); median predorsal scales 21 (20); scales from origin of first dorsal to midline of belly 6½. Gill rakers on first right gill arch 5 (6) + 1 + 19 (to 22).

Depth 5.0 (4.8–5.1); head 4.2 (4.0–4.2); snout to first dorsal origin 1.75, to centre of anus 1.9, to anal origin 1.5 (1.4); all in standard length. Snout 4.5 (4.2–4.6); eye 2.4 (2.2–2.4); tip of snout to rear of maxilla 2.8 (to 3.2); least depth of caudal peduncle 3.2 (to 3.4); postorbital length of head 2.2 (2.1–2.3); distance between dorsal origins 1.5 (1.4); length of longest ray of pectoral fin 1.3 (1.2); interorbital space 2.8 (2.6–2.8); all in length of head. Least depth of caudal peduncle in its length 2.4 (2.0–2.4). Lateral band broad, its greatest width 1.5 in postorbital length of head (counts and measurements from holotype, with ranges exhibited in the four paratypes included in brackets).

Premaxilla with front margin slightly convex; teeth minute on dentary, vomer, and palatines, on premaxilla giving a shagreen-like finish to outer surface; air bladder and body cavity ending bluntly in front of anal origin; bony edge of preopercle with concavity near lower posterior corner; gill rakers long and slender, longest ⅓ as long again as diameter of pupil; maxilla reaching to halfway between vertical lines through anterior margins of orbit and pupil; centre of anus posterior to tips of depressed ventrals, 1.5 vertical scale rows distant from tips; vertical line through anus passing through fourth scale in front of first dorsal origin; anal fin origin under third scale in front of second dorsal origin; posterior margins of scales smooth; ascending premaxillary process short, broad based, not entering interorbital space (Fig. 1*a*); mandible without an abrupt elevation posteriorly on each ramus (Fig. 1*b*).

The sequence employed in listing descriptive characters is after Schultz *et al.* (1953). The formula for recording fin counts is that now in use in many taxonomic works: upper case Roman numerals for spines or, as in this instance, nonstriated rays; lower case Roman numerals for striated, unbranched rays; and Arabic numerals for branched rays.

DIAGNOSIS: *P. capricornensis* cannot be distinguished from its congeners on any single feature. Combination of the following characters is diagnostic: the broad lateral band; the scale row count from upper limit of gill opening to caudal fin base; and the position of the anus relative to the tips of the depressed ventrals and first dorsal fin origin.

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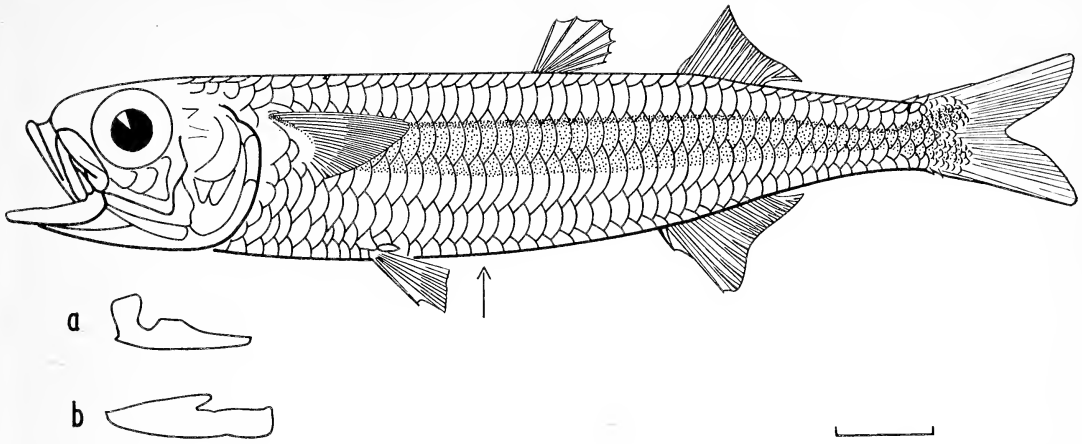

FIG. 1. *Pranesus capricornensis*, sp. nov., holotype, Queensland Museum no. I/8201 (scale line equals 10 mm.). *a.* Premaxilla; *b,* mandible.

COLOUR IN LIFE: Above lateral band, greenish; below band, silvery; lateral band silvery, but distinguishable from silver of belly by its more intense mirror-like finish; running from dorsal edge of pectoral base the full length of the upper limit of the lateral band a narrow (5.0 in width of lateral band) intense blue band terminating at root of caudal fin; a small blue spot on upper half of caudal fin scaly sheath; bluish crescent along upper ⅔ of base of pectorals; dorsals, caudal, and distal half of pectoral fins faintly dusky, other fins pale; peritoneum black.

COLOUR IN FORMALIN: Above lateral band, area lying under margin of each scale with dark pigmentation; lateral band black with a suggestion of the blue of the narrow band in its upper limits; area below lateral band pale; scaly sheath at base of caudal fin with two dark patches derived by anastomosing of lateral band; narrow bluish crescent on pectoral base persisting; colour of fins as in life.

ECOLOGY: Heron I. is a coral atoll 50 mi. from the Australian mainland (23° 27′ S., 151° 57′ E.). In the cooler months (Mar.–Aug.) immense schools of atherinids are common over the reef flat when it is flooded at high tide. All individuals taken from these schools proved to be a new species (*P. capricornensis*).

This fish was always seen swimming at depths of 1–3 ft. At low tides and during the warmer months it probably lives in open waters. The little tuna, *Euthynnus alleteratus affinis* (Cantor), which normally restricts its movement to open water, will venture on to the reef flat to feed on *P. capricornensis*.

Examination of alimentary canals of two adult fishes revealed various planktonic Crustacea, but the bulk of ingested material was unidentifiable. Females in spawning condition were recorded in Aug. 1956.

ACKNOWLEDGMENT: I would like to thank Richard J. Slack-Smith for donating specimens.

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New Pogonophora from the Eastern Pacific Ocean

Olga Hartman[1]

Continuing surveys, since 1955, of faunas in offshore areas of southern California, conducted by the Allan Hancock Foundation, using the facilities of the M/V "Velero IV," have resulted in finds of several representatives of pogonophorans. One, belonging to the genus *Siboglinum* Caullery, is believed to represent an undescribed species. Other kinds, from different places, are briefly reported below, to indicate the wide range of occurrences in deep ocean bottoms off southern California. All come from depths exceeding 950 m. and in latitudes south of 33° N. The much larger and far better explored shallower depths have yielded none, despite the examination of thousands of grab samples from shelf, slope, basin, and canyon depths of the shelf lands between Point Conception, California, to south of the Mexican border.

All specimens are deposited in the collections of the Allan Hancock Foundation. I am indebted to the Administration of the Foundation for permission and time to study these interesting materials. The cost of collecting the materials was defrayed by funds from the National Science Foundation and the Allan Hancock Foundation. Captain G. Allan Hancock has generously provided for any deficiencies in the running costs of the ship. The scientific and operating crews of the "Velero IV" took and processed the collections. Dr. Gösta Jägersten, Uppsala, Sweden, examined specimens and verified their generic affinities. The illustrations were prepared by Anker Petersen. I am indebted to all of these people for their help and interest.

genus *Siboglinum* Caullery, 1914

type *S. weberi* Caullery, 1944

Siboglinum veleronis, new species

Figs. 1–9

collection: More than 100 specimens were taken by the "Velero IV," sta. 7049, May 7, 1960, 14.85 mi. 264° true from Point La Jolla, 32° 49′ 37″ N., 117° 35′ 12″ W., in 976 m., from the axis of La Jolla canyon near its convergence with the San Diego trench. The Campbell grab, weighing about 900 lb. with a capacity of about 5 cu. ft., recovered 2.51 cu. ft. of gray sand and green mud. In addition to the *Siboglinum* specimens, the sample yielded the kinds and numbers of animals listed below.

diagnosis: Individual tubes measure 50–65 mm. long by 0.13 mm. across. Others are longer or narrower, having a length-to-width ratio of 450–720 to 1. Each tube is usually slender, cylindrical, pale to dark straw-colored, and crossed by alternating dark brown and pale bands. The brown ones are typically paired (Fig. 2), so that both of a pair are nearly twice as long as one pale band. An occasional irregularity in this pattern results when the two dark ones are so close together as to appear fused, or are incomplete on one side to form a broader than usual, incomplete, pale band. The greater length of the tube is crossed by these alternating cross bars; only the distal anterior and posterior ends (Fig. 1) are pale and usually collapsed. The animal within lies usually some distance within the banded region; none has been found partly or wholly out of the tube. With the aid of a stereoscopic microscope the specimen can be seen through the wall of the tube and oriented with respect to the anterior and posterior regions, the tentacle in front directed forward, and the annular or uncinial band marking the approximate middle region of the body. However, dissection is necessary to study the animal more completely. Slitting the tube lengthwise has been found least destructive to the soft-bodied specimen; by using a razor-sharp, finely pointed knife and inserting it into the distal end of the tube, then extending the cut lengthwise for the length of the contained individual, one can then lift it out intact from the shell of the tube.

An entire animal measures 15 mm. long to the annular, or uncinial, region which is near the middle, making the total length about 30

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mm. The body is nearly uniform in width but is widest in the mesosomal region where it measures 0.065 mm.; the postannular region gradually becomes slenderer and tapers posteriorly. The tentacle is less than half as wide as the body and extends forward for a length nearly two and a half times that of the mesosomal length. Its insertion marks the ventral side of the body as herein interpreted, as well as the posterior end of the first body region or protosoma. The three body regions are not sharply separated from one another. The separation between the first and second regions is behind the tentacular insertion and is vaguely indicated by a faint line extending obliquely forward around the body to the middorsum. The second region, or mesosoma, is about four times longer and is separated from the third region, or metasoma, by a transverse groove located just in front of the paired glandular papillae (see Figs. 5, 6). The third region is much the longest and comprises most of the length of the body.

The tentacle is extended forward nearly straight in some specimens and is loosely to closely coiled in others, or only a short distal end is coiled. Most of the length has lateral, filiform branches or pinnules, inserted in two nearly regular rows along the ventrolateral edge (Fig. 4); those nearer the distal end are more dispersed, whereas those nearer the base (Fig. 3) are closer together and tend to be curled toward the midventral line. Each pinnule is very slender and longer than the tentacle is thick. These features agree with those described for other species of the genus having pinnules; only two (*S. inermis* Ivanov and *S. atlanticum* Southward and Southward) are said to lack them.

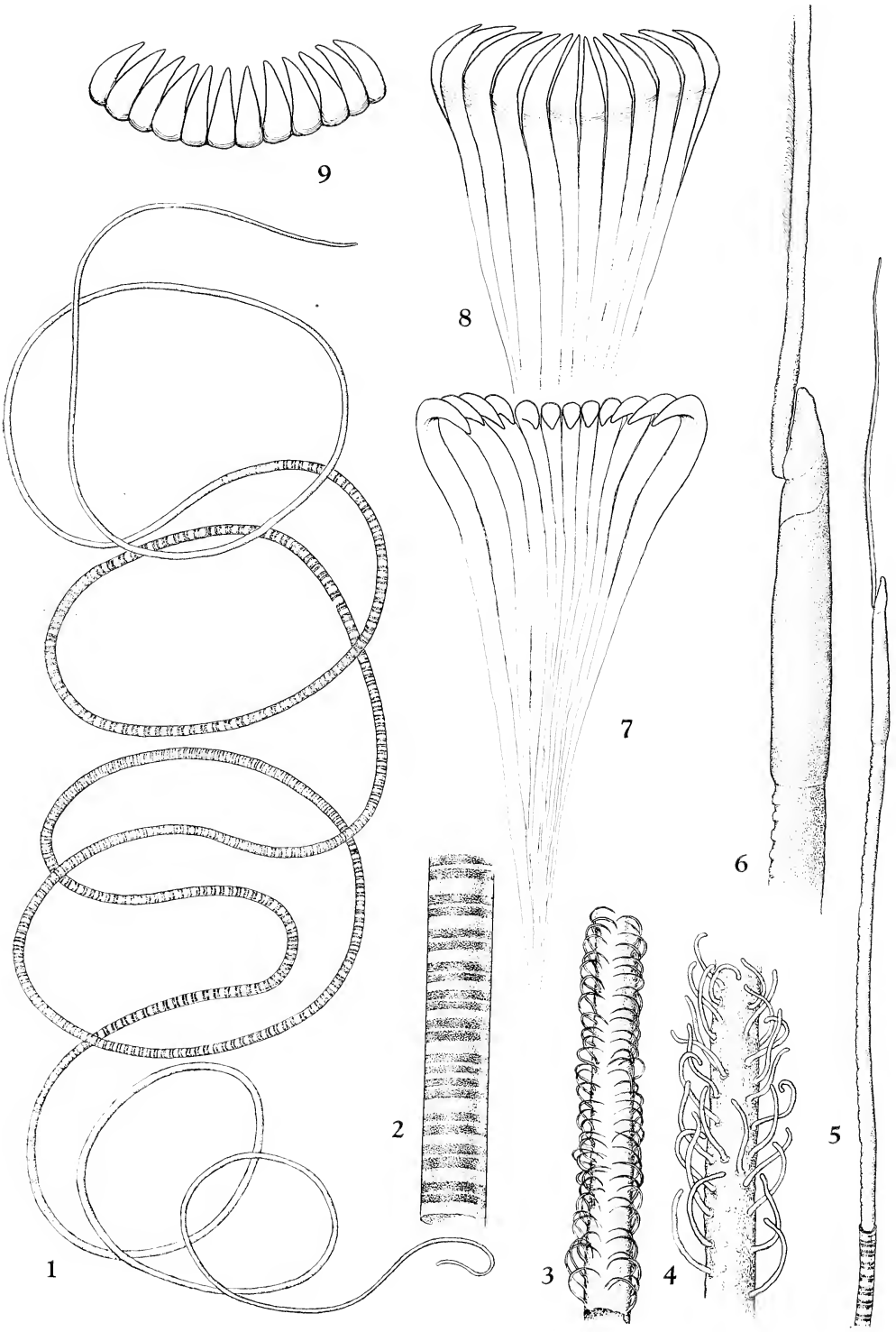
The protosoma or anteriormost region of the body is short, subconical, tapers forward, and lacks markings; its posterior end is indicated on the ventral side of the body by the insertion of the tentacle. This fusion is firm, so that the two are not easily severed. A mouth, if present, would be expected at the posterior base of this tentacle, for which the principal function seems to be that of food gathering. I have seen no oral aperture or any indication of an alimentary tube but would not exclude the possibility of a lengthwise transport tube of some kind in an animal of such great length.

The second body region, the mesosoma, is considerably longer than the first and is cylindrical in shape; near its anterior end it is obliquely crossed by the bridle or frenulum (Ivanov) or girdle (some other authors). It is separated from the third region, or metasoma, by a transverse groove. A pair of circular pores is located at the sides, just behind the frenulum (Fig. 6); they are believed to be the external apertures of the coelomoducts for the second segment.

The anterior end of the metasoma is characterized by the presence of ventrolateral paired glandular papillae; they are so arranged that the two members of a pair are separated from successive ones by a space about equal to that of the distance between the brown bars on the tube. It thus seems obvious that these papillar glands are directly concerned with tube secretion. This region is followed by the much longer goniadial region, characterized by sparsely and irregularly dispersed epithelial papillae. About halfway along the length of the body two transverse series of uncinial rows indicate the position of the annular region; for this reason the goniadial region in front is called the preannular, and the same one behind is the postannular, region.

The annulae are of particular interest because they bear hard, chitinized platelets, or unicini, in transverse series. Those of the anterior row are incomplete and number about 38, while those in the posterior row are more numerous, numbering about 44. All uncini are of one kind, and terminate distally in a single row of denticles (Fig. 8), numbering 9–13. Each uncinus is distally recurved so that those of successive uncini tend to overlap. Seen from the end the denticles form an arcuate row (Fig. 9). The basal or embedded stems are not chitinized but taper rapidly to very tenuous strands, and are so prolonged that all those of one transverse series are brought together as a fascicle and carried obliquely forward to attach to the body wall. They may function to anchor the animal within the tube at selected places. The comparable uncini in some other species, *S. atlanticum* and *S. inermis,* have been shown as having multiple rows of crenulations (see Southward and Southward, 1958: 629, 631).

S. veleronis was recovered from a quantitative sample covering a surface area less than a half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a square meter. The animals contained in the mud, without tubes, weighed about 6.4 g. (moist weight). They included the following:

Siliceous sponge spicules, scattered through the debris
Anemone, small white, 1
Crustaceans (not identified)
ostracod, 1; amphipod, 1; cumacean, 2; gnathid isopod, 2
Mollusks: more than 100 living small gastropods, pelecypods, and 3 small solenogasters (not identified)
Echinoderms, identified by Fred Ziesenhenne
Ophiacantha normani Lyman, 2
Ophiura kofoidi J. F. McClendon, 22
Polychaetes: with 22 species and more than 200 specimens
Ancistrosyllis tentaculata Treadwell, 3
Axiothella sp., 6
Aricidea aciculata Hartman, 3
A. uschakowi Zachs, 32
ampharetid, juveniles, 4
Brada glabra Hartman, 12
Chaetozone ?gracilis (Moore), 2
Chaetozone sp., fragments, 2
Cossura candida Hartman, juveniles, 2
Glycera ?capitata Oersted, juveniles, 2
Haploscoloplos elongatus (Johnson), 4
Heteromastus ?filobranchus Berkeley, 4
Maldane cristata Treadwell, 13 (the largest and most conspicuous in the sample, contained in thick, mudwalled tubes with lateral vents and branches)
Myriochele ?gracilis Hartman, juvenile, 1
Ninoe fusca Moore, 12
Nothria sp., juvenile, 1
Paraonis gracilis oculata Hartman, 77+
Pilargis hamata Hartman, 1
sabellid tube, 1
Terebellides sp., juvenile, 1
Tharyx monilaris Hartman, 10+
T. tesselata Hartman, 4
Pogonophora
Siboglinum veleronis, new species, 100+

The total number of species and specimens is thus 30+ and 428+.

SYSTEMATIC AFFINITIES: *S. veleronis,* the eleventh species to be described in the genus *Siboglinum,* differs from others in that the tube has double bands of dark brown bars, and the uncini of the annular region have 9–13 teeth in a single transverse row. The proportional lengths of the first and second body regions, shown in Figures 5 and 6, differ from those of other species.

It is noteworthy that all but two of the known species occur in far northern latitudes. Six come from the northwestern end of the Pacific Ocean; three others are from the northeastern part of the Atlantic. The first species of the genus, *S. weberi* Caullery, came from the Malay trench in great depths, and the present species is the first to be described from the western hemisphere. These species, with their distributions are as follows:

S. weberi Caullery, 1944, IndoPacific area, in 462–2060 m., in fine sand and mud.

S. ekmani Jägersten, 1956, Skagerack, northwestern Europe, in 487–650 m., clay.

S. caulleryi Ivanov, 1957, Ochotsk Sea, in 90–200 m., and other northwestern Pacific areas in depths of 23–8100 m., in the Kurile trench.

S. cinctulum Ivanov, 1957, northwest Pacific, in 3420 m., in the Kurile trench.

S. pellucidum Ivanov, 1957, southwestern part of the Bering Sea in 1740–4820 m.

S. minutum Ivanov, 1957, Bering Sea in 3740–3840 m., and Kurile-Kamchatka trench in 5540 m.

S. fedotovi Ivanov, 1957, southwestern part of the Bering Sea in 3330–3940 m.

S. plumosum Ivanov, 1957, Ochotsk Sea east of Japan, in 124–318 m.

FIGS. 1–9: *Siboglinum veleronis,* new species, from "Velero IV" sta. 7049. 1, Entire tube containing animal, × 22; 2, part of tube showing paired dark alternating with pale bands, × 89; 3, part of tentacle from near base, showing pinnules curled toward midventrum, × 228; 4, another part of tentacle from another individual, with pinnules nearer tip of tentacle, × 228; 5, animal with tube partly dissected away, tentacle directed forward, in left lateral view, × 25.5; 6, enlarged anterior regions including protosoma, mesosoma with frenulum and pore of coelomoduct, and part of glandular metasoma, in left lateral view, × 83; 7, an uncinus from annular zone, seen from denticled side, × 5,720; 8, an uncinus seen from opposite side, × 5,720; 9, an uncinus seen from top, showing arcuate arrangement of denticles, × 5,720.

S. atlanticum Southward and Southward, 1958, from the northeastern Atlantic, in 600–1400 m.

S. inermis Southward and Southward, 1958, from the same locality as the preceding.

S. veleronis, n. sp., from La Jolla canyon, southern California, in 976 m.

In addition to *S. veleronis,* the collections of the Allan Hancock Foundation contain representatives of three other pogonophores. One is mentioned earlier (Hartman and Barnard, 1960: 283) coming from West Cortes, East Cortes, and Long basins and from the San Diego trench. The collar segments of the tube measure 2.9 mm. across and 3.3 mm. long; each is drab dark brown, cylindrical, paler at one end where it flares and is frayed. In size and shape they most nearly resemble those shown for *Galathealinum* (Kirkegaard, 1956: 81).

Another kind, a *Siboglinum* sp., has just been received from a trawl station, "Velero IV," sta. 7231, off San Eugenio Pt., Lower California, Mexico, in 4800 m. This organism inhabits tubes which, in size and color, resemble those of *S. veleronis,* but the alternating brown bands are single, not double, and range from four to six times as long as the pale ones, or only a little longer. The protostoma has a pair of small red eyespots at the sides—the first known instance of eyes in pogonophores. The ventral side of the tentacle appears villous, due to paired rows of long, closely set pinnules. The uncini are in two transverse, single rows and are set far apart, the distance being about equal to four times that of the body width.

A fourth species is *S. ekmani* Jägersten, from the Skagerack, Denmark, a gift from the Zoological Museum at Copenhagen.

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Acanthophora, a Possible Invader of the Marine Flora of Hawaii[1]

MAXWELL S. DOTY[2]

IN THE FALL OF 1952, a small algal fragment was brought to the author from Pearl Harbor[3] by Mr. Charles Cutress. In April, 1953, a much larger piece of the alga was brought in by Mr. Spencer Tinker, who had found it washed ashore near the Waikiki Beach Laboratory of the University of Hawaii. Both collections were readily determined as representing a species of *Acanthophora* Lamouroux (1813: 132), a rhodophytan genus. This genus is distinct and clearly recognizable among the floral elements occurring in this part of the world. A search of the literature and the herbaria available revealed no Pacific records of this genus from the Hawaiian Islands or, with one exception, east of the Western Caroline and Marianas islands north of the equator.

Other collections during succeeding years, and field observations as well, revealed a huge increase in the abundance of the species in Hawaii during the next few years. In May, 1953, Dr. D. W. Strasburg found this alga "in abundance" at Keehi Lagoon, between Pearl Harbor and the Port of Honolulu on the leeward side of Oahu. Later the same month, a dense growth of the alga was found by the author (numbered 10774) and Dr. E. Y. Dawson at Hauula, north of Honolulu, on the windward side of the island of Oahu. Parts of this collection are the earliest collections from Hawaii represented in both the Bishop Museum and the University of California herbaria. From that time on, *Acanthophora* has been so common on the leeward side of Oahu that it has not often been preserved as an herbarium specimen.

Finally, during June, 1956, Dr. Otto Degener collected and sent in a specimen (his no. 24105) from Mokuleia on the windward shore of the island of Oahu, northwestward from Honolulu, collected by himself, Miss Marie Neal, and Dr. Constance Hartt, with the annotation ". . . ubiquitous some distance within the reef; observed very rare here last year. This is first time aggressive marine alga threatening native kinds." Certainly it appears to be replacing (crowding out) elements of the native flora. Degener, who has paid close attention to the reef population at this particular site, feels the alga probably was not there until, at most, 2 years before this collection was made.

Not only have frequency of observance and density of standing crop increased, but the distribution has been that of a progressive encircling of Oahu, one of the few islands of the Hawaiian Group where *Acanthophora* has been found.

The alga has spread to Kauai, another of the Hawaiian Islands. Mr. Jan Newhouse has passed on local stories that the alga was not found around Kauai until about 1954 or 1955, and the observation that it is now ubiquitous. This genus was recorded from Kauai by Kohn and Helfrich (1957: 243). Their mention of the genus was based on observations of Newhouse about November, 1956, and was not included among the algae they collected and had identified by Dawson at the time their earlier work (Helfrich and Kohn, 1955) was completed in October and November of 1955. It has been found neither among our earlier extensive collections from Kauai nor by Newhouse among his, but during August 1960, Dr. Charles Lamoureux and Mr. Tadayuki Kato made a collection (Lamoureux coll. no. 1542) of *Acanthophora* on Kauai at Poipu Beach.

Specific, though in part cursory, searches during 1960 for *Acanthophora* on the islands of

[1] This work was made possible by a research time grant from the Graduate Research Committee of the University of Hawaii and facilitated by Office of Naval Research contract 2591 (00).

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[2] Botany Department, University of Hawaii, Honolulu 14, Hawaii.

[3] According to Mr. Mikihiko Oguri, this algal collection probably came from West Loch, between Laulaunui Island and the northwestern shore.

Hawaii, Lanai, and Maui variously by Robert K. S. Lee, Mikihiko Oguri, Warren Wilson, and the author have resulted in no traces of this alga being found with one exception. The exception is a collection made by the author (numbered 19431), Mrs. Meng Sung Doty and Mr. Lee along the north shore of Lanai in November, 1960, where the alga was washed onto the muddy sand beach in abundance, free or attached to shells, coral, or even rocks up to 2 lb. in weight. Unfortunately, the Kawaihae area on Hawaii and the shores of Molokai have not been specifically searched for this genus, but our collections made during earlier years from these places do not include *Acanthophora.*

In the light of the ability and persistent vigor of the algologists who have at one time or another concerned themselves with the marine algae of the Hawaiian Islands, e.g., Drs. W. A. Setchell, Josephine Tilden, G. F. Papenfuss,[4] I. A. Abbott, and earlier, the Misses Minnie Reed and Marie Neal, and Mrs. Nina H. Loomis, it seems unlikely that this alga would have been overlooked had it been consistently present. It is a conspicuous alga. The older Polynesians in Hawaii seem to have had no name for *Acanthophora.* If pressed for a Polynesian name nowadays, the common man professing native acumen will apply local names such as manauea, the name widely used formerly for species of other genera, such as *Gracilaria* (now usually referred to by the Japanese name, ogo).

Identifying the Hawaiian alga has led to a consideration of the differences purported to exist between the several species reported in the Pacific. Many variants can be found in the material that has been available for this study from both the Atlantic and the Pacific, but for the present it is felt that the many forms found might best be treated as variants of one species. *Acanthophora spicifera*[5] (Vahl) Boergesen (1910) is the name for this species having priority insofar as we know.

Among the most common names[6] considered here as having been applied to the taxon *A. spicifera,* as found in the Pacific, is *A. orientalis* J. Agardh (1863). In describing *A. orientalis* as a new species, J. Agardh listed the Marianas Islands, of which Guam (13° N., 145° E.)[7] is one, as the source of one of the two collections he had seen. The other collection was probably from Manila Bay (14° N., 121° E.) in the Philippines. Safford (1905: 30–32) says that in the Marianas, the islands Guam, Rota (14° N., 145° E.) and Tinian (15° N., 146° E.) were visited by the Freycinet expedition. The material of this expedition from these islands is believed to be the source of one of the two collections Agardh reported. In his text, Safford (1905: 177 f.) lists *A. orientalis* from Guam and we presume this to be based on the Freycinet record, since Safford also says Dumont d'Urville collected several new species of algae on Guam. We ourselves have seen no specimens from Guam, despite a search through the several collections, now in our possession, which were made there by Mr. Ernani Meñez in 1960.

Except for the reports from Hawaii, the genus is not known to occur in the Pacific east of the Marianas other than in the Ponape region, where it has been reported by Yamada (1944: 44) as *A. muscoides* (L.) Bory from Ant (7° N., 158° E.), an atoll 8 mi. to the southwest of Ponape.

It is common about the large subcontinental or continent-related islands of the far western Pacific and, as *A. spicifera,* according to Womersley (1958), in northern Australia. The genus is reported (Kanda, 1944: 749) from Palau (7° N., 134° E.) as *A. orientalis.* As *A. thierii* Lamx. the genus is recorded from the Admiralty Islands (probably 2° S., 147° E.) and Tongatabu (21° S., 175° W.) by Dickie (1875*b*: 238, 235, resp.) and from Torres Straits (10° S., 143° E.) by Dickie (1876: 447). *Acanthophora* is common in the warmer part of the Atlantic, and Lamouroux (1813) believed the genus to be circumequatorial.

It seems entirely possible that this species

[4] In correspondence, Dr. Papenfuss tells us that neither he nor Setchell found this genus in Hawaii, and that the only Hawaiian specimens in the University of California herbarium are duplicates of the Hauula collections sent in by Dawson and mentioned above.

[5] Basonym=*Fucus spiciferus* Vahl, 1802.

[6] The only similar species not mentioned otherwise here appears to be *A. aoki* Okamura, 1934.

[7] The approximate latitude and longitude in degrees is given for the convenience of those interested in the location of the places named.

could have arrived in Hawaii from the west on a ship bottom, i.e., a man-made facilitation of the oceanic drift method of dispersal. This would be the carrying of an organism "upstream."[8] The progressive increase in abundance around the island over several years' time, and, recently, what appears to be a leveling off in abundance, is considered evidence of an introduction into the Honolulu–Pearl Harbor area. The Honolulu–Pearl Harbor shore area is the part of the state having the greatest traffic with regions of the world where *Acanthophora* has been known as a common component of the flora for a long time. This area is not climatically extreme for the state. However, since Honolulu has been in contact with the East and West via ship for centuries, it seems likely that some recent unusual occurrence may have implemented this transport. The three following events have come to our attention and are considered in this regard.

First, the recent warming of North Pacific waters (e.g., since the low temperature year of 1955 at Christmas Island, 2° N., 157° W.) would not, it seems, be accountable for the following reasons: first, the warm temperatures did not begin until after the alga was well known in Hawaii, and, secondly, there has been little abnormality of water temperatures in the Hawaiian area itself.

A second unsual event that may have led to the introduction is the increase in traffic between the Honolulu–Pearl Harbor area and the Far East during World War II, 1941–45, and during the Korean Police Action, 1950–53. The idea is that a number of small introductions at nearly the same time might have provided together a sufficiently large inoculation for the species to become established. From the rate of spread we tend to exclude the first period. The second is more timely. There is no special evidence that would lead one to choose this latter as the probable period, though such changes in oceanic traffic have been held to account for the distribution of barnacles in some cases elsewhere in the world.

A heavily fouled barge, the "Yon 146," towed to Pearl Harbor from Guam, provides an example of the third, and more specific, type of event that may have led to the establishment of *Acanthophora* in Hawaii. The idea here is that one heavily "fouled bottom" could have provided a sufficiently large inoculation for the species to become established. Upon arriving in Pearl Harbor February 3, 1950, this "fuel oil barge (non-self-propelled)" was placed in a dry dock. The Pearl Harbor dry docks are about 12 km. by water and 8 km. in a straight line from the place Cutress collected the first material of *Acanthophora* found in Hawaii. The dry dock is about 30 km. by water from the place Tinker first found this species of *Acanthophora.*

Fish and gastropod collections were made both from the growths, often 3–8 in. thick, on the barge and from the small pools left under the barge in the otherwise dry dry dock. They were made, at least in part, on April 10, 1950, and variously by Tinker, George Campbell, and Kenneth A. Wong. This vessel, 200 ft. long, 56 ft. in beam, concrete-hulled, under different descriptive names, has been mentioned as a possible means of fish introduction by several authors, e.g., by Gosline and Brock (1960: 26), who have studied collections made on it. The same vessel is reported by Edmondson (1951: 183, 212) as having brought in invertebrates which have become established,[9] such as the brachyuran crab, *Schizophrys aspere,* common to the far western Pacific. Chapman and Schultz

[8] This is the customarily postulated direction of migration in deriving the populations of Hawaii, as summarized by Zimmerman (1948), and Gosline and Brock (1960). Ladd (1960) has emphasized a somewhat different possible mode of origin for the populations of the Pacific islands.

[9] From accounts of long-time residents of the area, known distribution of the species, and information in the literature, it seems to me almost certain that *Cotylorhizoides pacificus* (Mayer) and *Cassiopea medusa* (Light), both Rhizostomae, were accidentally introduced to the Pearl Harbor area during the 1941–45 period. The type locality of these two medusae is the Philippine Islands. In Hawaii both were restricted to Pearl Harbor until about 1950. About this time, *Cassiopea* appeared in Honolulu Harbor and the Ala Wai Canal. Later, 1953–54, *Cotylorhizoides* appeared in Kaneohe Bay. Until the time of my departure (December, 1955) neither medusa was known from the other Hawaiian Islands, Line Islands, Marshalls, Gilberts, etc. Both forms undoubtedly came to Hawaii as scyphistoma on ships or the like, as neither are medusae of the open ocean.—C. E. Cutress, June, 1960.

(1952) concluded there was no evidence among the fish records they obtained that species had been brought to Hawaii in the fouling population on that barge. Dr. C. M. Burgess, who, along with Campbell and Tinker, provided much of the specific information on these events, told the author that the species of the molluscan genus *Cypraea* brought in on this vessel, the "Yon 146," did not become established in Hawaii, and this has been affirmed by Dr. Alison E. Kay, who is a student of this genus.

In commenting upon *Tripterygion hemimelas* Kner & Steindachner and *Ecsenius hawaiiensis* Chapman & Schultz, two blennioid fishes reported to have been collected from the pools of water in the dry dock holding the "Yon 146," Strasburg (1956: 245 f.) notes that the specimens of *T. hemimelas* were similar to a species from the Samoan Islands (14° S., 171° W.). The service record of this barge, as far as the author has been able to trace it, indicates that it was tied up at Apra (13° N., 145° E.), Guam, from 1945 to the date it was towed to Pearl Harbor, a period of about 4 years. Thus is does not seem likely that it would have been directly the means by which a Samoan fish would have been introduced into Hawaiian waters. Whether *T. hemimelas* occurs in Guam or not is not known to the present author.

Possibly the blennioid fish, *Omobranchus elongatus* (Peters), was brought to Hawaii (Strasburg, 1956: 257) from the Samoan area along with chunks of reef rock bearing living specimens of the giant clam, *Tridacna.* At least for the present, this splendid possible avenue of introduction is discounted; though *Acanthophora* has been reported (Reinbold, 1896) as *A. orientalis* from Upolu (14° S., 171° W.), Western Samoa.

Individual ships have been cited previously as the means by which algae have been introduced into the Central Pacific. Dickie (1875*a*: 33) published a note to the effect that *Ulva latissima* Linnaeus was introduced to Mangaia (22° S., 158° W.) in the Cook Islands when a whaling ship from the Antarctic was wrecked there on the reef in 1852. There is the possibility, however, that the wrecked ship merely provided a favorable habitat, in which habitat an ulvoid alga interpreted by Dickie as representative of this specific taxon appeared. In form the ulvoid algae, of the larger benthic algae, are among the most plastic in respect to environmental conditions.

Kohn (1959: 81) records *Acanthophora* (using the binomial *A. orientalis*) from Kaneohe Bay, Oahu, Hawaii, where it was the substratum upon which the eggs of *Conus quercinus* were found attached in February, 1956. *C. quercinus* has been recorded for Hawaii for many years (e.g., Bryan, 1915: 454), but the alga for only a few years. If *C. quercinus* is very host-specific in its egg-case depositing, this observation of Kohn's could be taken to imply long presence of *Acanthophora* in Hawaii. Though the alga is independent of the mollusc, if the mollusc is restricted to the algal species for egg-case deposition, the alga would probably have had to be here first and it would have taken many years for the mollusc to develop modified egg-case depositing habits including *Acanthophora* as a host. Our impression[10] is, however, that egg-case attachment by molluscs is not very specific, substratum-wise, and therefore, that there is no implication in Kohn's record that *Acanthophora* grew in the islands, say, in 1915.

After considering the types of events described above, we feel that it is most likely that *A. spicifera* arrived recently in Hawaii via the fouled bottom of a ship. Aside from the ordinary ship traffic, similar opportunities for introduction by vessels other than the "Yon 146" are known. One of these opportunities is provided in the case of a similar vessel, the "Yogn 41," which was towed from Subic Bay (15° N., 120° E.) in May, 1947. This "gasoline barge (non-self-propelled)" was dry-docked in February, 1950, in Pearl Harbor. While Subic Bay is unknown phycologically, *A. spicifera* is common in the general area, e.g., in Manila Bay a few miles to the south it is abundant. However, from the timing of the events and from the rate of spread after the first specimens were found, it is believed that

[10] A letter received since from Prof. J. M. Ostergaard supports this impression concerning the specificity of egg-case deposition by *Conus* and tells us of his "finds" of *C. quercinus* in the Honolulu Harbor area as dead shells in 1902 and 1905 and as living shells in 1915.

an earlier vessel would be much less likely a source of the introduction of *A. spicifera* than the "Yon 146."[11]

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[11] Though we do not know what other biological consternation may be associated with this vessel, it may cause little more for Hawaiian biologists, for it is reported to have been sunk in Subic Bay on October 16, 1955.

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Post-larval Food of the Pelagic Coelenterate, *Velella lata*

ROBERT BIERI[1]

HUGE, UNEXPECTED SWARMS of *Velella* that have drifted onto the coasts of France, England, the United States, and other countries have stimulated many of the studies on the "purple sail." Although recent reports (Savilov, 1958; Bieri, 1959) have indicated some of the reasons for the apparently haphazard appearance and disappearance of these swarms, we have little or no idea of the effect of such sporadic invasions on the local fauna. The size of these populations is indicated in several published reports, of which Woltereck's (1904) is typical. This particular swarm when cast onto the beach at Villefranche formed a mound ½ m. wide, ½ m. high, and fully 1000 m. long. Such huge populations must have a considerable effect on the community of organisms in the sea beneath them.

This paper records some quantitative data on the food of *Velella.* Some possible effects of predation by *Velella* on associated zooplankton are suggested.

MATERIAL AND METHODS

In the present study, 137 specimens were used. Ninety-nine of these were obtained by dip-net between 0915 and 1000 at 32° 41′ N., 121° 04′ W. on May 10, 1950. These specimens were sorted into five size-groups and preserved in formalin. On March 29, 1954, 38 specimens were collected in a special surface net between 1400 and 1500 at 32° 40′ N., 118° 16′ W., and were also preserved in formalin.

In the laboratory all gonozooids were cut from the specimens and examined at 12× magnification. Those parts containing visible food were removed and dissected, and the food items were identified. The main central gastrozooids were dissected separately. Details of the weight determinations are given in Bieri and Krinsley (1958).

RESULTS AND DISCUSSION

Only three brief comments on the food of *Velella* appear in the literature. Huxley (1858) found copepod remains in the gonozooids, while Lebour (1947) reported a young "macerated" *Velella* with its "stomach" (main central gastrozooid) full of harpacticoid copepods. Totten (1954) reported a calanoid copepod and crustacean remains in the gonozooids. No quantitative data are available.

In the present study most of the food was found in the gonozooids. Only 33 per cent of the specimens examined had food in the main central gastrozooids. Digestion occurs in both the gonozooids and the gastrozooid, as is evidenced by the exoskeletons of crustaceans found in both places. The food in the gastrozooid was somewhat larger on the average than that in the gonozooids. Possibly the gastrozooid ingests the organisms caught by the gonozooids that are too large for them to ingest. However, the gastrozooid also ingests small items.

In the 99 specimens taken off California in May 1950, fish eggs (mostly those of jack mackerel, *Trachurus symmetricus*[2]) made up 48 per cent of the total food by count. Euphausiid eggs made up 7 per cent of the food items. On the other hand, in 38 specimens taken off California in March 1954, euphausiid eggs made up 78 per cent of the food items and fish eggs 3 per cent by count.

The fish eggs had an average diameter of 1.1 mm., the euphausiid eggs a mean diameter of 0.41 mm. Thus a fish egg has nearly 17 times

[1] Antioch College, Yellow Springs, Ohio. The early stages of this study were carried out at the Scripps Institution of Oceanography, La Jolla, California, and the Lamont Geological Observatory, Palisades, New York. Manuscript received July 29, 1960.

[2] Dr. E. H. Ahlstrom, U. S. Fish and Wildlife Service, La Jolla, Calif., kindly identified the fish eggs.

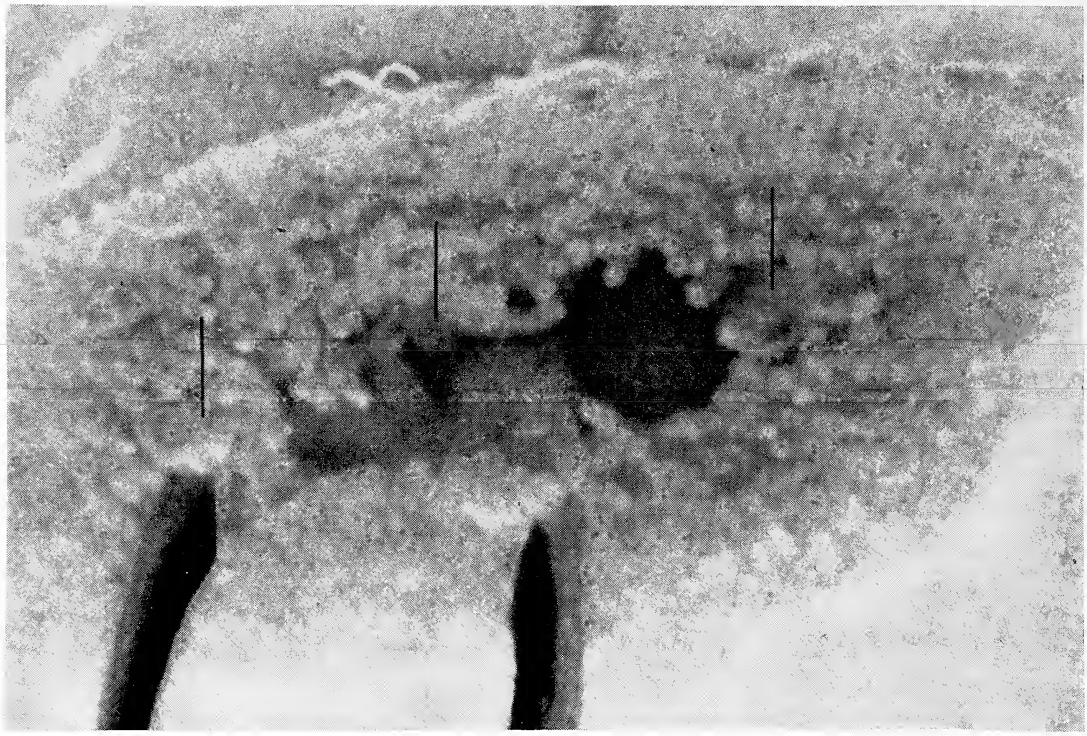

FIG. 1. Ventral side of *Velella* killed and fixed in process of eating three large and three smaller fish eggs. Smaller eggs, marked by vertical lines, have diameter of 1.1 mm. Gastrozooid surrounding central egg has broken and appears as thin film above egg. Darkest egg is not completely ingested.

the volume of a euphausiid egg. This means that in the *Velella* taken in March of 1954, fish eggs almost equalled the volume of euphausiid eggs in the diet of *Velella,* while in the May 1950 sample fish eggs were 120 times the volume of euphausiid eggs. The ventral side of a *Velella* taken in the process of eating six fish eggs is shown in Figure 1.

When the *Velella* were collected in March 1954, a surface net tow was taken at the same time. In Table 1 the per cent composition of the plankton is compared to the per cent composition of the food of *Velella.* Euphausiid metanauplii and copepods were 10 times as common in the plankton as in *Velella* food. On the other hand, euphausiid eggs were nearly 8 times as common in the food of *Velella* as in the surface zooplankton. Larvaceans, which made up 10 per cent of the food by count, formed less than 0.1 per cent of the plankton. If the plankton sample is representative of the food that was available to this particular *Velella* population (change with time or micro-vertical distribution differences may mean the plankton sample is not representative), it appears that motile organisms such as copepods and nauplii are not caught as effectively as are weaker swimming zooplankton, such as the larvaceans or the nonmotile eggs of fish and invertebrates. Nevertheless, comparatively large and active organisms such as larval fish and adult euphausiids are occasionally caught.

In Figure 2 the per cent composition by count of the food of the 99 specimens taken in May 1950 is shown as a function of mean length of *Velella.* Apparently there is no marked food selection by the different sizes of *Velella* although the calanoid copepods (3) increase steadily in importance when *Velella* surpasses a length of 30 mm. This is another indication that motile organisms are not caught as effectively as are nonmotile objects. Besides jack mackerel eggs and the items listed in Table 1, the following items were found in the gono-

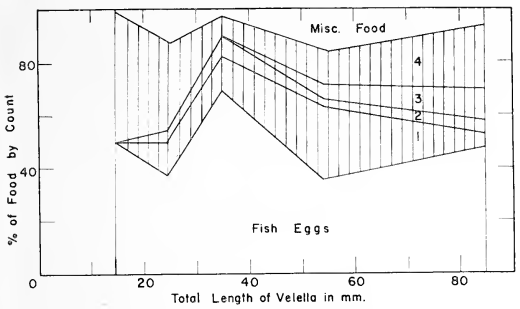

FIG. 2. Per cent composition, by count, of *Velella* food as function of total length of *Velella.* Shaded area is crustacean food. *1,* Euphausiid eggs, *2,* barnacle cyprids, *3,* calanoid copepods, *4,* other crustacean food. There appears to be no marked food selectivity by the different sizes, although copepods increase in importance in diet at sizes above 30 mm.

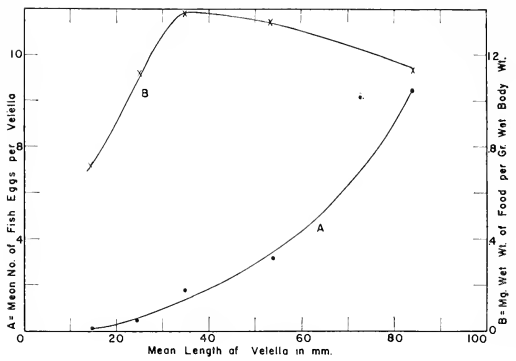

FIG. 3. Amount of food caught as function of length of *Velella.* Although number of fish eggs increases rapidly with length, weight of food caught per gram of wet body weight decreases after length of about 40 mm.

zooids and main central gastrozooids of *Velella* but were not studied quantitatively: larval fish, including a saury; chaetognaths and their eggs; barnacle nauplii, probably of *Lepas;* siphonophores; larvae of decapod Crustacea; adult mysids; copepod eggs and nauplii; larval and adult euphausiids; corycaeid copepods; pteropods. *Velella* also were found to have eaten the diatom *Coscinodiscus* and the medusae of other *Velella.* One specimen had eaten a fish scale. Specimens cast upon the beach were found to have ingested sand into the gastrozooid as well as into the gonozooids. Thus it appears that *Velella* is a carnivore, feeding on anything it can catch, generally weakly swimming or nonmotile zooplankton.

In Figure 3 the mean number of fish eggs caught by various sizes of *Velella* is shown as curve *A.* The number increases rapidly with increasing length of *Velella.*

The amount of food in each size group of *Velella* was too small to allow reliable weight determinations. Therefore, the wet weight of food present was estimated by calculating the volume of the fish eggs, assuming their density to be one, and assuming that the crustacean food on the average was one-third the weight of the fish eggs. On the basis of these assumptions, the weight of food caught per gram wet body weight of *Velella* is shown as a function of the length of *Velella* (Fig. 3, curve *B*). At lengths greater than about 40 mm. the *Velella* increase in weight more rapidly than they increase the amount of food caught.

TABLE 1

FOOD OF *Velella* COMPARED TO ASSOCIATED ZOOPLANKTON

BY COUNT	% OF *Velella* FOOD (38 specimens)	% OF PLANKTON (0–½ m. net tow)
Euphausiid eggs	78	10
Euphausiid metanauplii	0.5	52
Copepods	3	34
Anchovy eggs	3	3
Other fish eggs	0.5	<0.1
Larvacea	11	<0.1
Barnacle cyprids	0.5	<0.1
Hyperiid amphipods	0.5	<0.1
Cladocera (*Evadne*)	1.0	<0.1
Emerita larvae	1.5	<0.1
Parasitic copepods, *Caligus*	0.5	<0.1

CONCLUSIONS

The data given above indicate that *Velella* is essentially carnivorous, feeding more or less indiscriminately on zooplankton primarily within the size range 0.2–10 mm. Motile organisms are not caught as effectively as nonmotile forms. *Velella* may be an important predator on fish eggs, which make up a major part of its diet. Euphausiid eggs are also an important part of its food. Off the California coast the seasonal appearance of *Velella* on the surface is correlated with the spring spawning of pelagic fish, such as hake, saury, sardine, and jack mackerel. The relatively greater abundance of suitable food during the spring months may be one of the factors responsible for the seasonal cycle of reproduction and growth in *Velella.*

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Interspecific Differences in the Reaction to Atropine and in the Histology of the Esophagi of the Common California Sea Hares of the Genus *Aplysia*

LINDSAY R. WINKLER and BERNARD E. TILTON[1]

DURING A STUDY of the effects of certain cholinergic agents on the tissues of *Aplysia,* it was noted that the esophagi of the two California species (*A. californica* and *A. vaccaria*) reacted divergently to atropine. This is of interest to both the taxonomy and physiology of the genus as well as potentially to a better understanding of the mode of action of atropine. Other drugs commonly known to show activity on muscle tissue were also tested on the two species to determine if any other interspecifically divergent reactions existed. These pharmacological reactions will be reported later.

Botazzi (1898) observed the periodic contractions of the esophagus of the European *Aplysia* and made a thorough study of its physiology. The physiology of the crop was studied extensively by von Brücke (1905). Straub (1907) reported the reaction of the heart of an unspecified species of *Aplysia* to muscarine and noted the lack of atropine antagonism in the heart ventricle. Hogben (1924) studied the reaction of the crop of an European *Aplysia* to epinephrine.

MATERIALS AND METHODS

Small- to medium-size specimens of *Aplysia (Neaplysia) californica* Cooper and *Aplysia (Aplysia) vaccaria* Winkler were collected during the summer months at Lunada Bay, Palos Verdes, Los Angeles Co., California. The animals were packed in wet *Pelvetia fastigata* and transported to the laboratory where they were maintained in a 10-gal. salt water aquarium until needed. A Cole-Parmer model all-plastic impeller-type pump drew the water from the aquarium through a filter containing glass wool and activated charcoal and pumped it serially through two 5 gal. carboys maintained in a refrigerator. It was thus possible to keep the water clean and cooled to approximately the temperature of the intertidal environment of these animals. Parsley obtained in the local market was eaten in quantity by *A. californica* but was refused by *A. vaccaria.* Consequently all specimens of the latter were used as soon as practicable.

Animals were sacrificed by incising the entire length of the foot, turning the animal inside out and removing the esophagus after tying it at both ends. The esophagi were suspended from a plastic holder in conventional baths using 30 ml. of sea water. The movable end of the esophagus was ligated to a Grass force-displacement transducer, which was connected to a Grass amplifier-recorder.

To identify the two types of excursions noted in the tracings, cross sections of esophagus tissue were tied on opposite sides of the ring thus formed so as to obtain tracings of the contractions of the circular muscle with little or no effect from the longitudinally oriented tissue. Atropine was used in 1:1000 solution (1 mg/ml) in all cases.

For histological examination both longitudinal and cross sections were made using standard techniques. These were stained with eosin and hematoxylin. Sections were also made of all the noticeably differentiated areas of the digestive tract.

EXPERIMENTAL RESULTS

The normal pattern of contraction as recorded from the isolated esophagus consists primarily of comparatively rapid short excursions which vary in frequency and amplitude. These may be interspersed with occasional contractions of greater amplitude, especially in *A. californica* (Fig. 1*a*). Since the latter contractions were ab-

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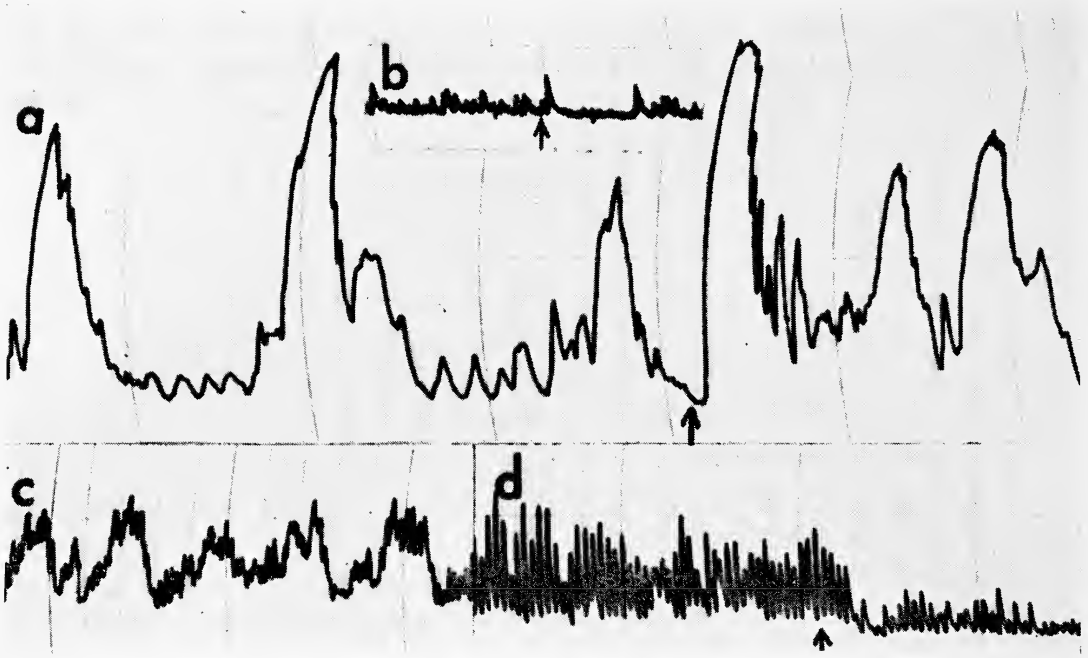

FIG. 1. The normal tracing of the esophagus of *A. californica* is indicated in *a* and the effect produced by 0.2 mg. of atropine solution added to the 30 ml. bath is shown at the arrow. The depressing of the circular contractions of a ring of esophagus by 0.2 mg. atropine is shown in *b*. Tracings *c* and *d* show two types of normal tracings obtained from *A. vaccaria* esophagus and the effect of 0.4 mg. atropine added at arrow.

sent when the rings of esophagus were used (Fig. 1*b*), they are attributed to longitudinally oriented muscle in contrast to a primary circular muscle response. For some unknown reason the rapidity of contraction was increased when the esophagus was arranged in rings. The deep, intermittent excursions are not as pronounced in *A. vaccaria* (Fig. 1*c*) and may be absent (Fig. 1*d*). The response of circular muscle, however, is consistently more rapid and more pronounced than is the case in *A. californica.*

In *A. californica* even very small doses (0.05 mg. in some cases) of atropine produce an immediate and unfailing but transitory contraction of the longitudinal muscle (Fig. 1*a*). The esophagus of *Aplysia vaccaria,* however, does not react to atropine except in comparatively large doses of 0.4 ml. or more (in a 30 ml. bath), in which case the excursions of the circular muscle are depressed (Fig. 1*d*). The circular muscle of *A. californica,* as demonstrated by the muscular ring preparations, is noticeably depressed by atropine in even smaller doses than that required to depress the circular type muscle in *A. vaccaria* (Fig. 1*b*). This depression was not noticed in the usual tracings of *A. californica* muscle since it was obscured by the longitudinal contractions. Other muscle-active drugs with specific reactions of interest in themselves (which are to be reported later) did not produce divergent results between the two species.

In an attempt to gain an insight into possible reasons for the divergence of reaction between the two species, histological sections were made and stained with eosin and hematoxylin. Strongly eosinophilic bundles of coarse, cylindrical muscle strands were observed in the esophagus of *A. californica* (Fig. 2*a, b*). These strands appear coarsely striated in some preparations (Fig. 2*b*) and coarsely granular in others, the differences possibly representing problems in killing and fixing. The nuclei are larger and more sparse than those of *A. vaccaria* (Fig. 2*c, d*) and of the surrounding more conventional muscle of the present species. Not only are the nuclei three times as large but they tend to be arranged across the muscle strands, thus appearing rectangular in section. This muscle is

contrasted with the less eosinophilic, more undulatory muscle of the circular (Fig. 2*a*) and *A. vaccaria* type muscle (Fig. 2*c, d*), which is very heavily nucleated. While strands of a type of muscle which seems morphologically to be somewhat similar to the former type of muscle appear sparsely in the crop, and to even a lesser extent in the area between the gizzard and "stomach" of the digestive tract in *A. californica,* none of the eosinophilic muscles observed in other parts of the digestive tract of *A. vaccaria* possessed the distinctive tubular shape with the vacuolation, striation or granulation, and lack of undulatory characteristics.

DISCUSSION AND CONCLUSIONS

While it might be tempting to assume that the histological differences represent the immediate cause of the divergent pharmacological reactions observed, they are better interpreted as visible, easily demonstrable, morphological differences which parallel and are closely associated with neurohumoral and even biochemical differences which are themselves the underlying mechanistic causes. This is especially true since the effect of atropine on conventional tissue systems is thought to be on the neuromuscular receptors. The contractatory response observed in *A. californica* appears to be the transitory result of stimulation, since the mechanical stimulation of washing will produce similar contractions. However, the sensitivity to this chemical stimulation is very great, being as low as 0.05 mg. atropine placed in the 30 ml. bath—a concentration of $1{:}6\text{x}10^{5}$. Such a sensitivity represents a very delicately balanced chemical system.

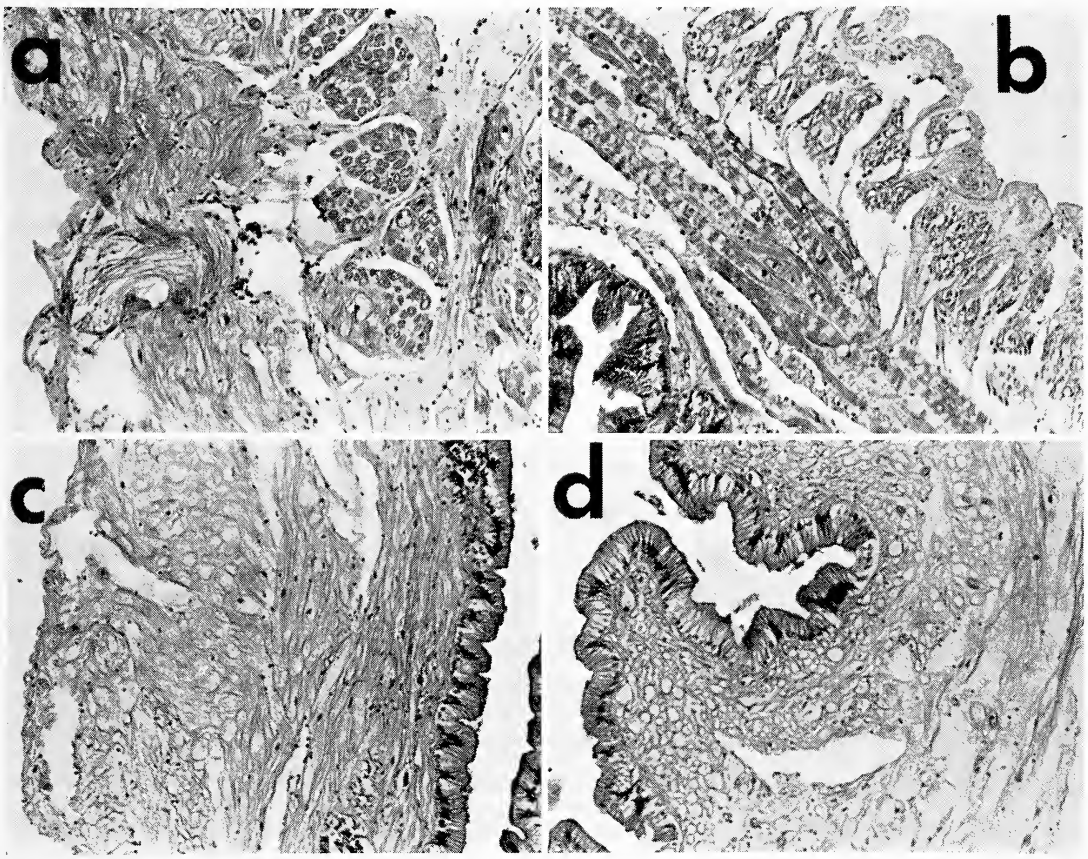

FIG. 2. *A. californica: a,* cross section; *b,* longitudinal section. *A. vaccaria: c,* longitudinal section; *d,* cross section. The midsection of the esophagi were used for cross sections.

Moreover, the mechanism is of special interest since it is unique among known muscle preparations in that it is stimulated rather than depressed by atropine.

The drug reaction and histological difference accentuates the divergence present within the genus. *A. vaccaria* belongs to a large and widespread subgenus (*Aplysia*), while *A. californica* (subgenus *Neaplysia*) is unique to the Californias. When it becomes possible to study comparatively the members of the two other subgenera[2] (*Varria* and *Pruvataplysia*), a taxonomic generalization may be possible. However, Bottazzi (1898) in his physiological study of the esophagus indicated that *A. limacina* (almost certainly *A. fasciata* of subgenus *Varria*) was much more atonic than the close relative of *A. vaccaria* (subgenus *Aplysia*) with which he also worked. Since it is thought that *A. californica* is an offshoot of this subgenus *Varria,* and since its esophagus is far from atonic by any interpretation, it may be that the musculature of the former has diverged considerably from its forerunners.

It would also seem quite probable that more comparative studies of the tissues of the species contained in other genera of animals would reveal occasional divergences of at least equal magnitude. Such a possibility cannot safely be overlooked in experimental biology in any of its phases, and accentuates the need for accurate taxonomy before proceeding with studies which may be of a nontaxonomic nature.

[2] Specimens of esophagus tissue from these subgenera were kindly supplied from existing museum material on hand by Dr. N. B. Eales but, unfortunately, the conventional preservation method employed by the collectors was not adequate for any type of conclusions.

SUMMARY

1. The normal pattern of esophageal contractions in *Aplysia californica* consists of short rapid contractions attributed to circular muscle, interspersed at intervals by deep excursions attributed to the longitudinal musculature. These secondary contractions are less pronounced and less regular in *A. vaccaria.*

2. Atropine causes marked contraction of the esophagus in *A. californica,* even in low concentration, but in *A. vaccaria* it depresses circular activity in higher concentrations.

3. The esophagus of *A. californica* has longitudinal bundles of cylindrical muscle appearing coarsely striated or granular. These have not been found in *A. vaccaria,* and are suggested as being associated with the mechanistic cause for the differences in reaction noted.

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The Vegetation of Yanagi Islet, Truk, Caroline Islands

PETER J. R. HILL[1] and BENJAMIN C. STONE[2]

YANAGI ISLET, located midway between Moen and Dublon in Truk lagoon (7° 24′ N.; 151° 53′ E.) is a small islet roughly 30 ft. high, about 800 ft. long and 300 ft. wide, with scarcely any strand but with volcanic rock pavement on all shores, and on the south side, numerous loose volcanic boulders. Much of the volcanic rock of which the islet is formed appears to be a breccia resembling conglomerate. The reef surrounding the islet is rather large, with small storm-deposited rocks on the northeast sides. There is a smallboat pass on the west side and another pass, probably safe for small craft, on the north side. During World War II, the Japanese tunnelled through the islet from a cave on the south side to the north side; another Japanese cave on the south side does not run all the way through the islet. A small-gauge railroad ran from the tunnel into the lagoon, for loading operations. The track is now rusty and twisted.

The vegetation, despite the obvious prior use of the islet for military purposes, is relatively undisturbed in a few small areas. The Trukese do not live on the islet, but visit it occasionally for fish and shell-fish, and perhaps for mangoes. There are only a few coconut palms and a few of their seedlings.

The vegetational zonation of the islet appears to comprise three areas: (1) a fringe area, more or less encircling the islet at sea level. (2) An open, rock-strewn extremity on the east, with a herbaceous cover, which slopes toward the east and terminates abruptly as a low cliff. This area is similar to the Tunnuk-Penniasene and Mechitiu lava flows, but here there is no polygonal-patterned basalt. (3) An inner upland, with a developed tree-cover and fairly good soil. There is in fact a transitional area of low-crowned shrubs between zones 2 and 3; it is not known whether this is a natural attenuation in plant size, accompanied by increasing dominance of the herbaceous cover, which has persisted, or whether it is a result of human disturbance. However, the area contains a U. S. Navy Survey bench-mark on a concrete base (without further information).

The most interesting features of the islet are the complete absence of coralline rock and soil, and the absence of most of the halophytic species of littoral plants which are so common elsewhere in Truk, a lack which is no doubt correlated with the nature of the substrate. The plants of Yanagi are by no means unique, and may be commonly found in Truk, and indeed through much of Micronesia. They are not restricted to volcanic soils, for some of them, at least, are known from the atolls nearby as well. But the strand species such as *Scaevola Taccada, Messerschmidia argentea, Terminalia samoensis,* and *Soulamea amara* are notably absent. Most of the species which occur on Yanagi also occur on the reef islets of Truk in coralline soil; but the lack of these littoral plants, which might reasonably be expected to grow there, is the curious and interesting feature of Yanagi Islet.

VEGETATION ZONES: Since the islet is so small, altitudinal considerations are of no account above sea level. The fringe area (1) seems to differ from the inner upland area (3) chiefly because of the exposure of the former and its hindrances to undisturbed plant growth, partly because of subjection to change from wind and waves, and to the concomitant salt spray, and partly because of the abundant volcanic boulders but thin, scanty soil. The grassland (2) and the intermediate area of shrubs may be the result of disturbance, or, again, may be the result of hard, thin soil with numerous embedded rocks, combined with exposure to wind and illumination. Salt spray is apparently minimized by the

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reef, which lies many feet from the islet's shore. No rainfall records are available; however, the inner forest with its better development of soil- and tree-cover no doubt accumulates moisture and retains it longer than the grassland and fringe area, with their porous volcanic boulders.

1, Fringe Area. A, Upper story: **Desmodium umbellatum* (L.) DC., common, the trunk to 10 cm. diameter; **Colubrina asiatica* (L.) Brongn., common, shrubby; **Clerodendron inerme* (L.) Gaertn., common scandent shrub; **Callicarpa candicans* (Burm.) Hochr., scattered; **Barringtonia asiatica* (L.) Kurz, scarce, only small plants seen; **Guettarda speciosa* L., only on south side; **Allophylus timorensis* (DC.) Bl., on south side; **Ficus* sp., on south side; **Premna obtusifolia* R. Br., on south side only; **Wedelia biflora* (L.) DC. ex Wight, scandent shrub; **Morinda citrifolia* L.—B, Vines: *Abrus precatorius* L.; **Ipomoea digitata* L.; **Passiflora foetida* L.; *Dioscorea* sp.; **Ipomoea pes-caprae* L., only one plant seen, in a small area; **Derris elliptica* (Roxb.) Bentham.—C, Ground cover: **Microsorum scolopendria* (Burm.) Copel.; *Vernonia cinerea* (L.) Less.; *Echinochloa colonum* (L.) Link; **Tacca leontopetaloides* (L.) Ktze., scattered and rare; **Digitaria pruriens* (*Trin.*) Büse.—D. Epiphytes: **Asplenium* sp.; **Davallia solida* (Forst.) Sw.; **Dendrobium* sp.

2, Grassland. A, Herbaceous cover, extreme eastern end of islet: **Digitaria pruriens* (Trin.) Büse; *Paspalum dilatatum* (?); *Chrysopogon aciculatus* (Retz.) Trin.; *Paspalum conjugatum* Berg.; *Cyperus* sp.; **Fimbristylis atollensis* St. John; *Emilia sonchifolia* DC.; *Phyllanthus amarus* Schum. & Thonn.; **Portulaca samoensis* v. Poelln.; **Microsorum scolopendria* (Burm.) Copel., a dwarf form.—B, Transitional zone, with shrubs; merging with 3: *Desmodium* sp. (seedlings); *Hedychium coronarium* Koen. & Retz.; **Barringtonia asiatica* (L.) Kurz, one seedling; **Tacca leontopetaloides* (L.) Ktze.; *Abrus precatorius* L.; **Premna obtusifolia* R. Br.; **Passiflora foetida* L.; *Abelmoschus* sp.; *Capsicum frutescens* L.; *Cocos nucifera* L.(a few young trees); **Morinda citrifolia* L.; **Colubrina asiatica* (L.) Brongn.; **Canavalia microcarpa* (DC.) Piper.

* Species marked with an asterisk are indigenous.

3, Inner Upland Forest Area.—A, Trees: *Mangifera indica* L.; *Musa balbisiana* X *acuminata; Carica Papaya* L.; **? Terminalia catappa* L.; **Ficus tinctoria* Forst.; *Erythrina variegata* L.; *Cocos nucifera* L.—B, Shrubs: **Colubrina asiatica* (L.) Brongn.; **Morinda citrifolia* L.; **Glochidion ramiflorum* Forst.; **Polyscias grandifolia* Volkens.—C, Ground cover: **Oplismenus compositus* (L.) Beauv.; *Paspalum conjugatum* Berg.; *P. dilatatum* (?).—D, Vines: **Canavalia microcarpa* (DC.) Piper; *Abrus precatorius* L.; **Piper fragile* Benth.—E, Epiphytes: **Davallia solida* (Forst.) Sw.; **Microsorum scolopendria* (Burm.) Copel.

All plants mentioned are represented by specimens in possession of the senior author.

ANIMALS PRESENT: The terrestrial animals, excluding insects and other invertebrates, were noted and identified by William R. Newman. Two species of lizard were fairly common, *Emoya cyanura* and *E. boetgeri.* The birds noted were *Aplonis opacus angus,* the Micronesian starling; *Demigretta sacra sacra,* the reef heron (dark phase); *Myzomela cardinalis major,* the cardinal honey-eater; *Collocalis inquieta rukensis,* the Carolines swiftlet; and *Gygis alba,* the fairy tern.

SUMMARY

The small volcanic islet in Truk Lagoon called Yanagi is remarkable for the lack of coralline development and the lack of halophytic vegetation which are common elsewhere on Truk. The vegetation appears to comprise three zones, which are called the fringe area, the grassland area, and the upper inland forest. The summit is about 30 ft. above sea level, and the islet is surrounded by a reef. Though occupied during the war, the vegetation is now fairly recovered from disturbance. A list of the plants occurring in each vegetation zone, and a brief note on some animals observed, is given.

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Revision of the Genus *Pandanus* Stickman, Part 6
New *Pandanus* Species from Queensland, Australia

HAROLD ST. JOHN[1]

THIS PART of the author's revision of the genus *Pandanus* is a collection of new species, all from the tropical northeastern corner of Queensland. They were all collected by L. J. Brass.

Pandanus sphaericus sp. nov. (sect. *Australibrassia*)
Figs. 23–24
NOM. VERN.: "maia."

DIAGNOSIS HOLOTYPI: Arbor 6–7 m. alta, trunco gracile "eo et ramis cum spinis brevibus conicis, ramis reflexis, radicibus fulturosis paucis 2–3 cm. longis," foliis 1.5 m. longis 3 cm. latis subcoriaceis gladiatis in apice subulato longiter attenuatis, puncto 10 cm. ex apice 1.5 mm. lato, basi inermi, sed ex 5 cm. marginibus cum subulato-serris pallidis 0.5–1 mm. longis 2–4 mm. distantibus, midnervio inermi, in regio mediali marginibus cum serris 0.5–0.7 mm. longis 1.5–3 mm. distantibus apicibus subulatis, midnervio infra cum serris 0.2–0.3 mm. longis 2–7 mm. distantibus adscendentibus, proxima apice marginibus et midnervio infra cum serris 0.2–0.3 mm. longis 2–3 mm. distantibus adscendentibus apicibus subulatis, pedunculo 26 cm. longo curvato cum bracteis foliosis paucis, syncarpio 12 cm. diametro subgloboso pendente circa 15 phalangibus ferentibus, eis 4.3–4.6 cm. longis 3.9–4.3 cm. latis 3.1–3.2 cm. crassis suborbicularibus sed subcompressis 4–5-angulosis in sicco pallide brunneis exlucidis laevibus, lateribus valde curvatis parte ⅔ supera libera, apice truncato, suturis lateralibus nullis, sinibus centralibus apicalibus 4–5 mm. profundis anguste V-formatis, carpelis 9–11, apicibus anguste pyramidalibus sed cum regione proximali truncato et dimidio proximali duro brunneo lucido ad stigmatam dirigito, stigmatibus 1.5 mm. longis ellipticis ad ovatis sulcatis in apice latere proximo, suturis proximis ½–¾ ad fondam extentis, endocarpio submediali 2.5–3 cm. longo osseoso pallide muris lateralibus 4–5 mm. crassis, seminibus 13–17 mm. longis 4 mm. diametro ellipsoidis, mesocarpio supero caverna unica 1 cm. longa cum fibris multis traversis formanto, mesocarpio basali fibroso et carnoso.

DIAGNOSIS OF HOLOTYPE: Tree 6–7 m. tall; trunk slender, it "and the branches studded with short conical thorns; branches down-turned; prop roots few, 2–3 dm. long"; leaves 1.5 m. long, 3 cm. wide, subcoriaceous, rapier-like and tapering from the base to the long subulate tip which 10 cm. down is only 1.5 mm. wide, the base unarmed, but beginning 5 cm. from the base the margins with subulate serrations, pale, 0.5–1 mm. long, 2–4 mm. apart; the nearby midrib unarmed; at the midsection the margins with subulate-tipped serrations 0.5–0.7 mm. long, 1.5–3 mm. apart; the midrib below with ascending serrations 0.2–0.3 mm. long, 2–7 mm. apart; near the tip the margins and midrib below with subulate-tipped ascending serrations 0.2–0.3 mm. long, 2–3 mm. apart; peduncle 26 cm. long, curving, with a few leafy bracts; syncarp pendent, 12 cm. in diameter, subglobose, of about 15 phalanges, these 4.3–4.6 cm. long, 3.9–4.3 cm. wide, 3.1–3.2 cm. thick, suborbicular, but somewhat compressed, 4–5-angled, when dried light brown, dull, smooth, the 4–5 sides strongly curving, upper ⅔ free; the apex truncate, lateral sutures none; central apical sinuses 4–5 mm. deep, narrow V-shaped; carpels 9–11, the apices narrow pyramidal with a proximal truncation and its inner half leading to the stigma hard, brown, shining; stigmas 1.5 mm. long, elliptic to ovate, creased, at tip of steep proximal face of apex; below it the proximal suture running ½–¾ way to valley bottom; endocarp submedian, 2.5–3 cm. long, bony, pale throughout, the lateral margins 4–5 mm. thick; seeds 13–17 mm. long, 4 mm. in diameter, ellipsoid; upper mesocarp a single cavity 1 cm. long, with many strong longitudinal fibers; basal mesocarp fibrous and fleshy.

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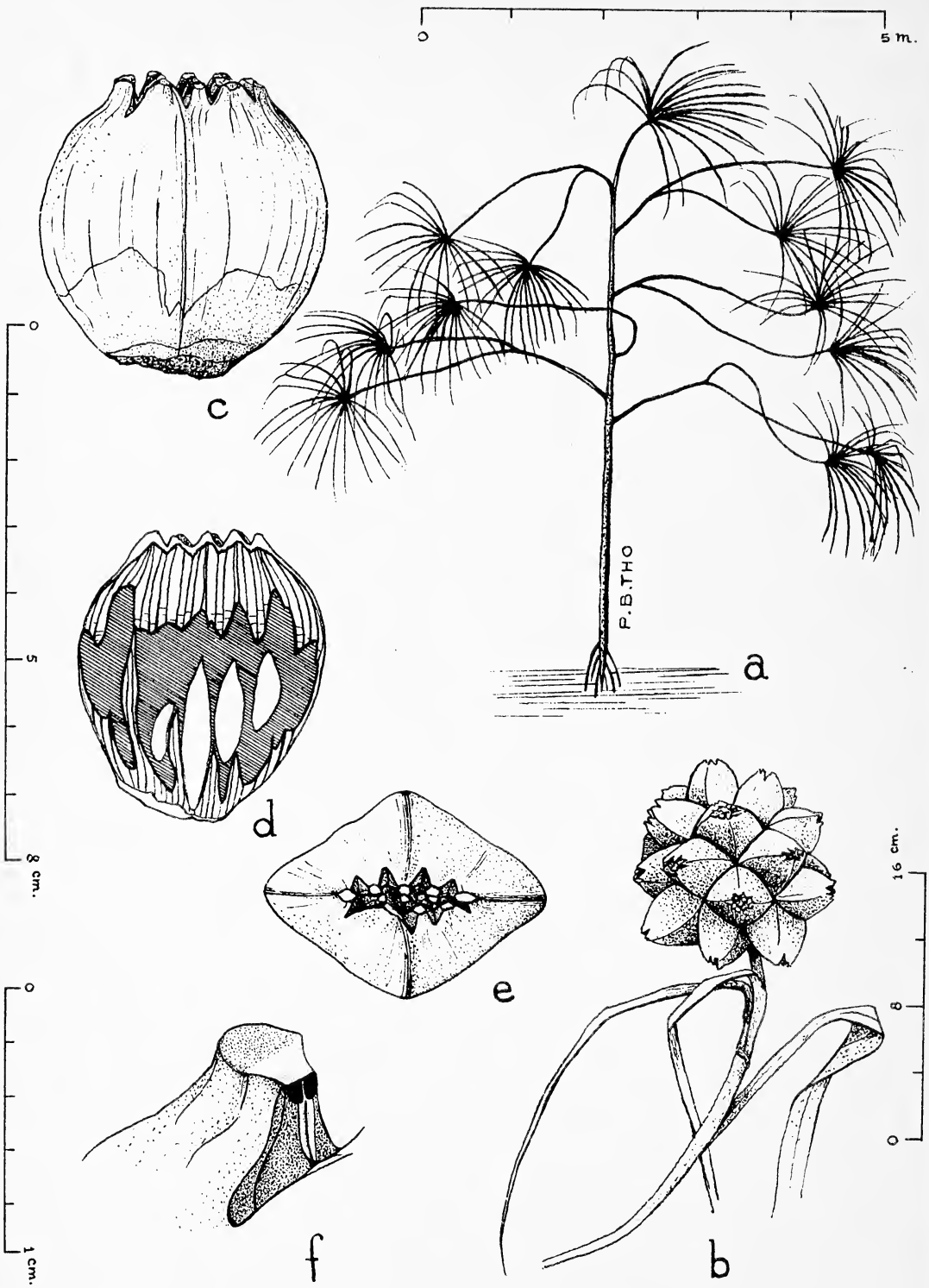

FIG. 23. *Pandanus sphaericus*, from holotype. *a*. Habit, × 1/70; *b*, syncarp, × ¼; *c*, phalange, lateral view, × 1; *d*, phalange, longitudinal median section, × 1; *e*, phalange, apical view, × 1; *f*, carpel apex and stigma, oblique view, × 4.

HOLOTYPUS: Australia, Queensland, Cape York Peninsula, abundant locally in rain forest behind the coastal sand dunes, 20 m. alt., May 9, 1948, *L. J. Brass 18,715* (BRI).

DISCUSSION: *P. sphaericus* is a member of the section *Australibrassia* and there also is its nearest relative, *P. cochleatus* St. John, which is distinguished by having the phalanges pyriform; the carpels 12–16; stigma below an overhanging cochleate rim; prop roots absent; and leaves having near the base marginal teeth 1.3–2 mm. long. It also occurs on the Cape York Peninsula. *P. sphaericus* differs by having the phalanges suborbicular; carpel 9–11; stigma on proximal face of carpel apex without an overhang; prop roots few; and leaves near base with marginal teeth 0.5–1 mm. long.

The new epithet is the Latin adjective, *sphaericus,* spherical, in reference to the shape of the phalange and of the syncarp.

Pandanus ferrimontanus sp. nov. (sect. *Pandanus*)
Figs. 25–26

DIAGNOSIS HOLOTYPI: Arbor 5–7 m. alta 10–12 cm. diametro in corona laxa ramosa, radicibus fulturosis nullis, foliis 133–160 cm. longis 5.8 cm. latis subcoriaceis glaucis supra infraque gladiformatis gradatim ex basi in apice subulato longe acuminato diminuentibus, in puncto 10 cm. ex apice 3 mm. latis, marginibus ex basi per 29 cm. inermibus tum cum aculeis 2–3 mm. longis 6–21 mm. distantibus subulatis adscendentibus apice brunneo, midnervio inermi, in sectio mediali margine unica cum aculeis 1–2 mm. longis 2–6 mm. distantibus adpresse adscendentibus subulatis cum basi crassa, margine altera cum aculeis paucis simulantibus sed minoribus vel in partibus inermibus, midnervio infra cum aculeis paucis remotis minutis adscendentibus, in regione apicali marginibus et midnervio infra cum aculeis 0.2–0.3 mm. longis 3–5 mm. distantibus subulatis validis adscendentibus, pedunculo 40 cm. longo excedenti obscure trigono folioso, syncarpio 16 cm. longo 14 cm. diametro terminali solitario ovoideo-globoso cum circa 45 phalangibus, eis 4.5–4.7 cm. longis 4.2 cm. latis 3.4–3.5 cm. crassis late obovoideis subcompressis, apice rotundato, parte ⅓ supera libera, lateribus cum 5–6 angulis majoribus et carpela quoque cum 2–4 angulis et valleculis angustis et tum lateribus phalangiorum proximorum interobseratis, in sicco lateribus papillosis et parte supera rubro-brunnea, suturis lateralibus angustis in dimidia supera, sinibus apicalibus centralibus 3.5–4.5 mm. profundis fondis angustis sinuosis et lateribus interobseratis, carpelis 8–12 plerumque 9–10, apicibus subaequalibus semiorbicularibus pallide brunneis sed lateribus brunneo-rimosis, regione obliqua brunnea concava ex stigmate distalia, stigmatibus 1–1.5 mm. longis ellipticis vel truncatis obscure brun-

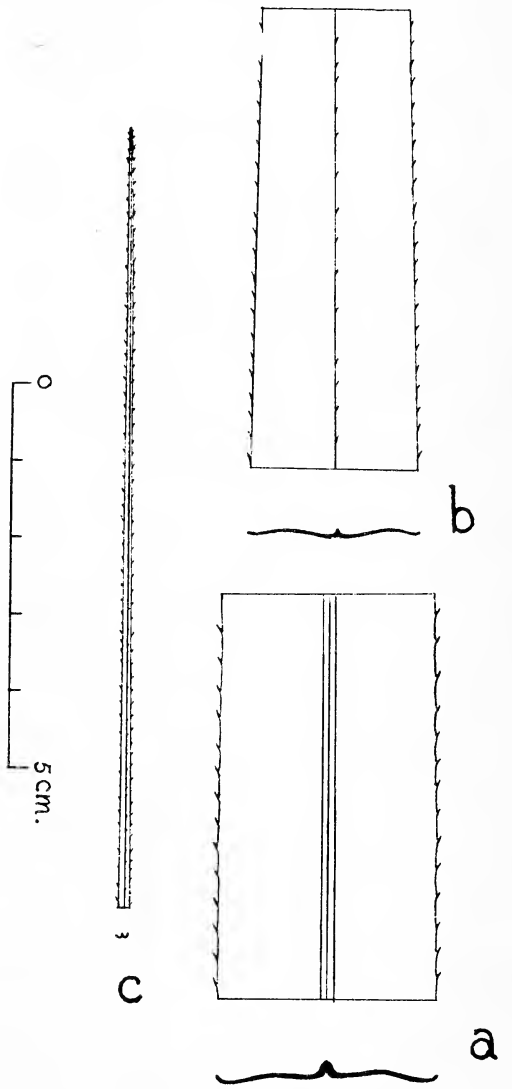

FIG. 24. *Pandanus sphaericus,* from holotype, lower side of leaf, × 1. *a,* Near base; *b,* middle; *c,* apex.

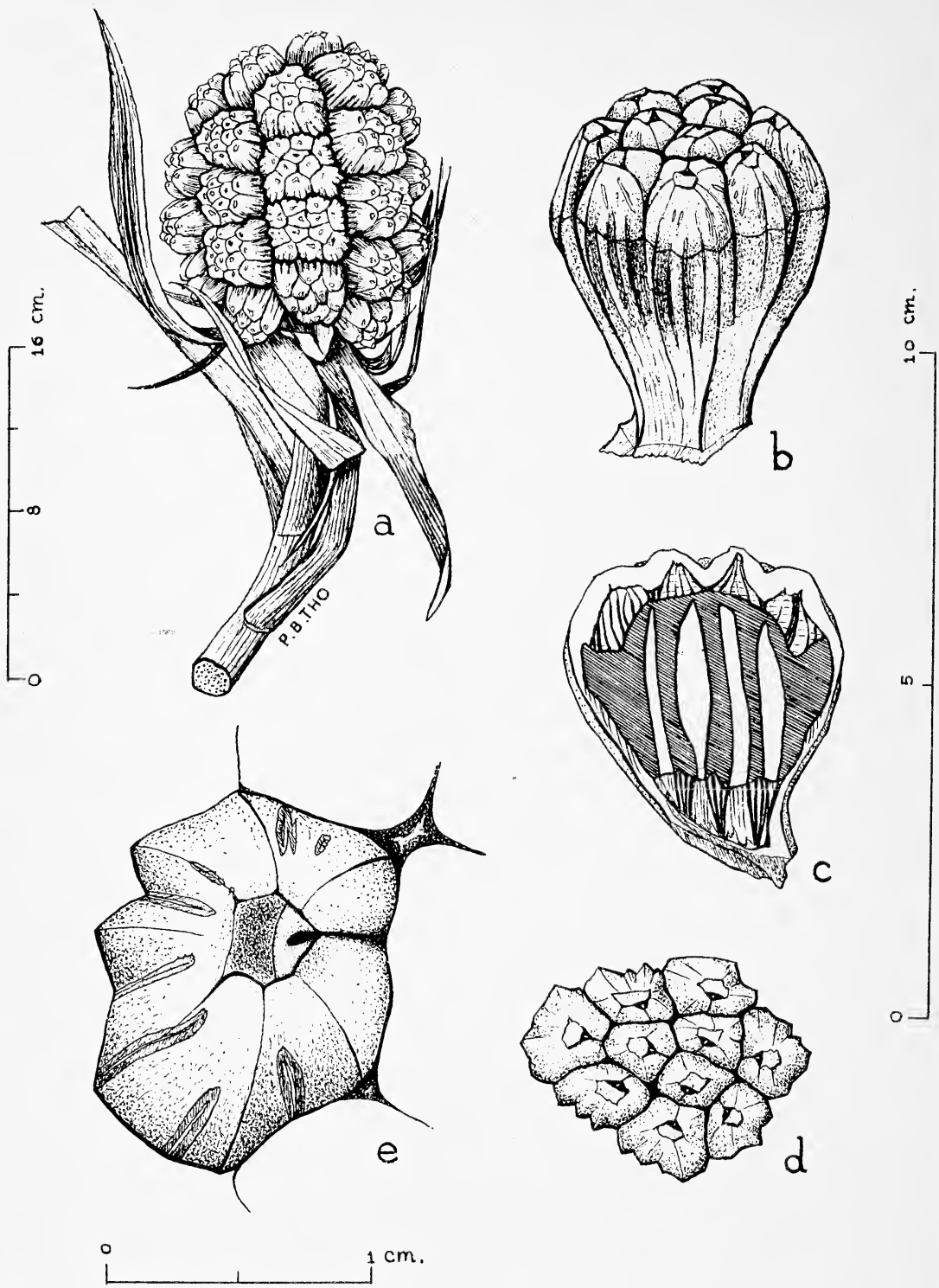

FIG. 25. *Pandanus ferrimontanus,* from holotype. *a,* Syncarp, × ¼; *b,* phalange, lateral view, × 1; *c,* phalange, longitudinal median section, × 1; *d,* phalange, apical view, × 1; *e,* carpel apex with stigma, apical view, × 4.

neis obliquis sulcatis centripetalibus, sinu proximo profundo ½ vel omnino distancia ad fondam extento, endocarpio 22–25 mm. longo supramediali osseoso stramineo lateribus lateralibus 8–10 mm. crassis, interiore cavernarum seminarum brunneo, seminibus 18–20 mm. longis 3–5 mm. diametro irregulariter ellipsoideis, mesocarpio apicali in carpella quoque cavernam cum fibris paucis et membranis stramineis transversis medullosis formanti, mesocarpio basali fibroso et carnoso.

DIAGNOSIS OF HOLOTYPE: Tree 5–7 m. tall, 10–12 cm. in diameter, branched into an open crown; prop roots none; leaves 133–160 cm. long, 5.8 cm. wide, subcoriaceous, glaucous above and below, sword-like, gradually tapering from near the base to the long acuminate, subulate tip which 10 cm. down is 3 mm. wide, the basal margins unarmed for 29 cm., then with prickles 2–3 mm. long, 6–21 mm. apart, subulate, ascending, brown-tipped; the nearby midrib unarmed; at the midsection one margin is with prickles 1–2 mm. long, 2–6 mm. apart, broad based subulate, appressed ascending, the other margin with a few similar but smaller prickles or intermittently with none; the midrib below with a few remote, minute, ascending prickles; near the apex the margins and midrib below with prickles 0.2–0.3 mm. long, 3–5 mm. apart, stout subulate, ascending; peduncle more than 40 cm. long, obscurely trigonous, leafy bracted; syncarp solitary, terminal, 16 cm. long, 14 cm. in diameter, ovoid-globose, the color unknown, of about 45 phalanges, these 4.5–4.7 cm. long, 4.2 cm. wide, 3.4–3.5 cm. thick, broadly obovoid, somewhat flattened, the apex rounded, upper ⅓ free, the sides with 5–6 major angles and each carpel with 2–4 sharp secondary ridges and valleys so that adjacent phalanges fit as if mortised, when dry the sides papillose and the upper part reddish brown; lateral sutures narrow but extending half way down; central apical sinuses 3.5-4.5 mm. deep, the bottoms narrow and sinuous mortised; carpels 8–12, mostly 9–10, the apices subequal, semiorbicular, the sides with dark brown cracks, elsewhere pale brownish, with an oblique distal, brown concavity leading to the stigma; stigma 1–1.5 mm. long, elliptic or truncate elliptic, creased, dark brown, oblique, centripetal; proximal sinus deep, running ½ way

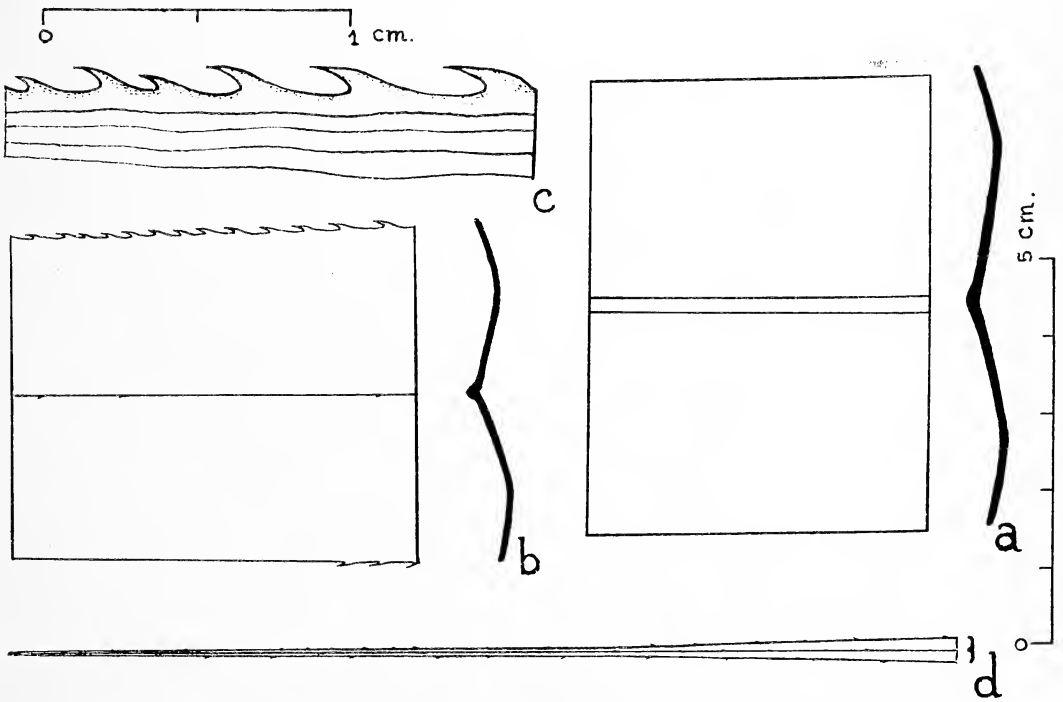

FIG. 26. *Pandanus ferrimontanus,* from holotype, lower side of leaf. *a,* Near base, × 1; *b,* middle, × 1; *d,* apex, × 1; *c,* marginal serrations at middle, × 4.

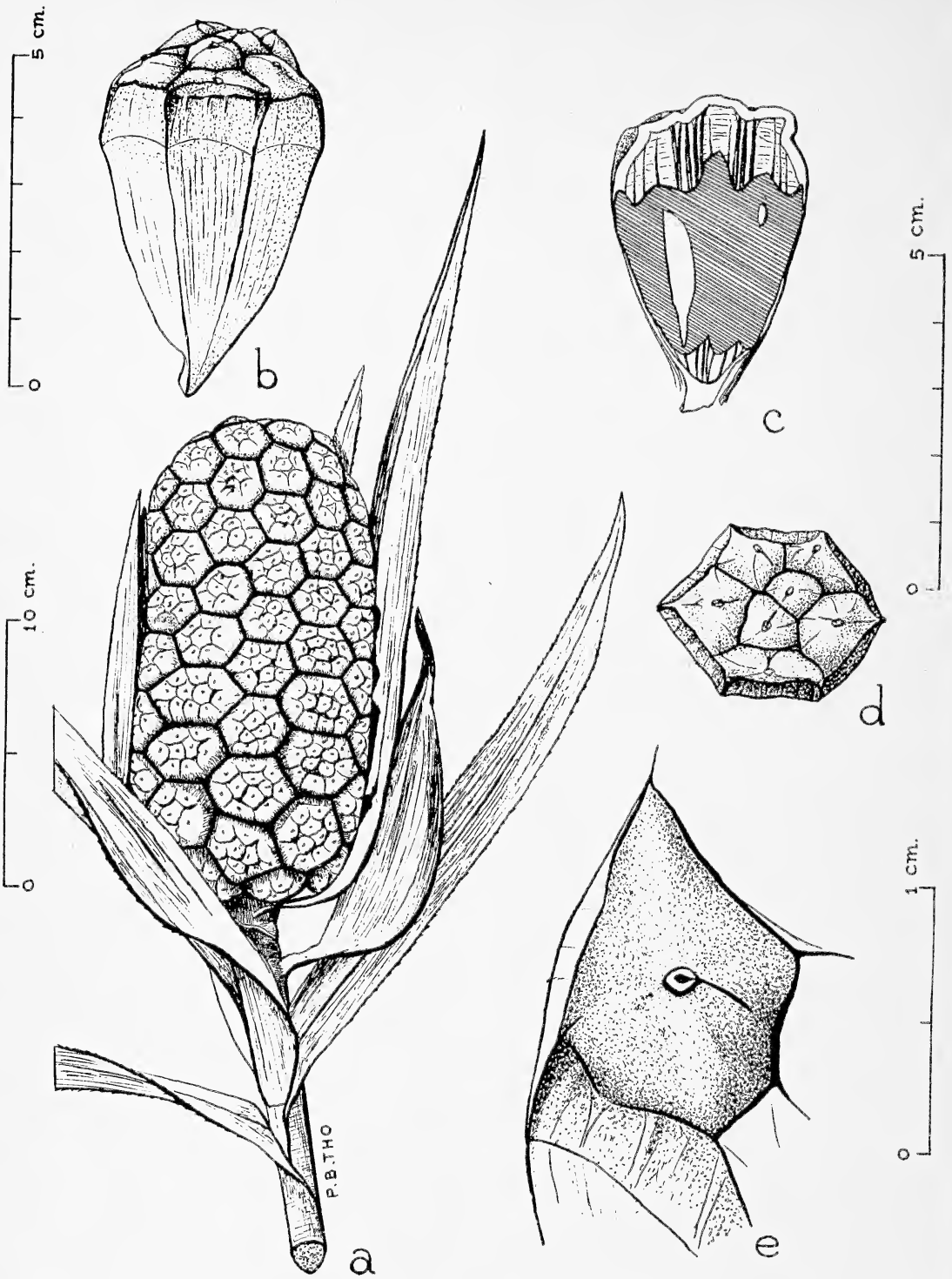

FIG. 27. *Pandanus oblatus,* from holotype. *a,* Syncarp, × 2/5; *b,* phalange, lateral view, × 1; *c,* phalange, longitudinal median section, × 1; *d,* phalange, apical view, × 1; *e,* apex of carpel and stigma, apical view, × 4.

to all the way to the valley bottom; endocarp supramedian 22–25 mm. long, bony, stramineous except for the dark brown, shining lining of the seed cavities, lateral walls 8–10 mm. thick; seeds 18–20 mm. long, 3–5 mm. in diameter, irregularly ellipsoid; apical mesocarp in each carpel forming a cavern with a few strong, longitudinal fibers, and transverse, stramineous, medullary membranes; basal mesocarp fibrous and fleshy.

HOLOTYPUS: Australia, Queensland, Cape York Peninsula, Iron Range, scattered or gregarious in groves in savanna forest, 20 m. alt., June 24, 1948, *L. J. Brass 19,312* (BRI).

DISCUSSION: The flowers were not seen by the collector. This new species is a member of the section *Pandanus,* to which most of the Australian species belong. None of the previously described species are close relatives, so no contrast is needed here.

The new specific epithet is formed from the Latin, *ferrum,* iron; *montanus,* of the mountain, in reference to the name of the type locality.

Pandanus oblatus sp. nov. (sect. *Pandanus*)
Figs. 27–28

DIAGNOSIS HOLOTYPI: Arbor 12–14 m. alta, trunco "crasso, corona ramosa, radicibus fulturosis multis longis spinosis," foliis 1.6 m. longis 9.2 cm. latis crassiter coriaceis infra subglaucis, in section valde M-formatis, gladiformatis gradatim in apice subulato trigono valide diminuentibus, in regione 10 cm. ex apice 5–6 mm. latis, basi amplexicauli et integri sed ex 7 cm. marginibus cum aculeis 2–3 mm. longis 3–6 mm. distantibus subulatis validis luteis subadscendentibus, midnervio infra inermi, in regione mediali marginibus cum aculeis 1.5–3 mm. longis 3–5 mm. distantibus subulatis validis arcuato-adscendentibus, midnervio infra salienti acuito et cum aculeis 2.5–3 mm. longis 10–20 mm. distantibus simulantibus adscendentibus; in regione apicali marginibus et midnervio infra subulato-serratis serris 0.8–1.2 mm. longis 2–3 mm. distantibus, pedunculis 15 vel plus cm. longis obtuse trigonatis folioso-bracteatis, syncarpio 18 cm. longo 13 cm. diametro cylindrico sed apicibus ambis rotundatis cum circa 92 phalangibus, eis 4.7–5.1 cm. longis 2.9–3.5 cm. latis 2.4–2.7 cm. crassis obovoideis in sicco rubro-

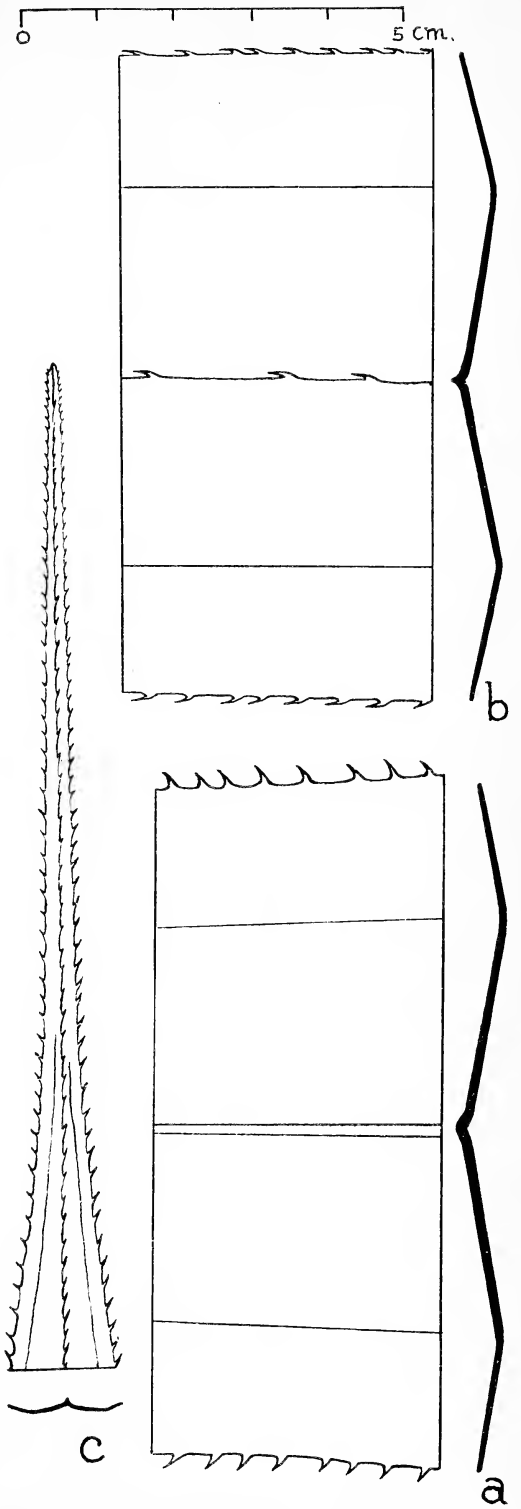

FIG. 28. *Pandanus oblatus,* from holotype, lower side of leaf, × 1. *a,* Near base; *b,* middle; *c,* apex.

brunneis 4–6-angulosis, lateribus papillosis subcurvatis vel paene planatis parte ¼ supera libera, apice rotundato, suturis lateralibus nullis, sinibus apicalibus centralibus 2–4 mm. profundis late V-formatis, carpelis 5–12 sed in phalangibus dimidiae superae plerumque 6–7 et in eis inferis plerumque 10–11, apicibus centralibus oblato-semiorbicularibus, eis marginalibus oblato-pyramidalibus, stigmatibus 1–1.8 mm. longis suborbicularibus ad ovalibus sulcatis obscuris apicalibus centripetalibus plerumque obliquis, sinu proximali lato ½ distancia ad fondam extento, endocarpio mediali osseoso obscure brunneo excepta marginibus pallidis, lateribus lateralibus 4–5 mm. crassis, seminibus 16 mm. longis 4 mm. diametro ellipsoideis, mesocarpio apicali in carpela quoque caverna cum membranis pallidis medullosis formanti, mesocarpio basali fibroso et carnoso.

DIAGNOSIS OF HOLOTYPE: Tree 12–14 m. tall; trunk "thick, crown branched; stilt roots many, long, and prickly"; leaves 1.6 m. long, 9.2 cm. wide, thick coriaceous, below slightly glaucous, in section sharply M-shaped, sword shaped, gradually narrowed to the stout, trigonous, subulate apex, this 10 cm. down is 5–6 mm. wide, at very base amplexicaul and entire, but from 7 cm. up the margins with prickles 2–3 mm. long, 3–6 mm. apart, stout subulate, yellow, slightly ascending, the nearby midrib unarmed below; at midsection the margins with prickles 1.5–3 mm. long, 3–5 mm. apart, stout subulate, arcuate ascending; the midrib below sharp, salient, with prickles 2.5–3 mm. long, 10–20 mm. apart, similar, ascending; near the apex the margins and midrib below subulate-serrate, the teeth 0.8–1.2 mm. long, 2–3 mm. apart; peduncle 15 or more cm. long, obtusely trigonous, leafy bracted; syncarp 18 cm. long, 13 cm. in diameter, cylindric but with the ends rounded, of about 92 phalanges, these 4.7–5.1 cm. long, 2.9–3.5 cm. wide, 2.4–2.7 cm. thick, obovoid, when dried reddish brown, 4–6-angled, the sides minutely papillose, gently curving or nearly plane, upper ¼ free, the apex rounded; lateral sutures none; central apical sinuses 2–4 mm. deep, wide V-shaped; carpels 5–12, those of the upper half mostly 6–7, those of the lower mostly 10–11, the central apices oblate-semiorbicular, the marginal ones oblate-pyramidal; stigmas 1–1.8 mm. long, suborbicular to oval, creased, dark, apical, centripetal, mostly oblique; proximal sinus wide, running ½ way to the valley bottom; endocarp median, bony, dark brown except for the pale outer margins, the lateral walls 4–5 mm. thick; seeds 16 mm. long, 4 mm. in diameter, ellipsoid; upper mesocarp in each carpel forming a cavern nearly free of fibers but with pale medullary transverse membranes; basal mesocarp fibrous and fleshy.

HOLOTYPUS: Australia, Queensland, Cape York Peninsula, Iron Range, occasionally in gullies in rain forest, 20 m. alt., June 24, 1948, *L. J. Brass 19,309* (BRI).

DISCUSSION: The new species is a member of the section *Pandanus*. In this the closest relative seems to be *P. odoratissimus* L. f. var. *novoguineensis* (Martelli) St. John, which as the phalanges 5.7–6 cm. long, 3–3.5 cm. wide, the lateral sinuses distinct in the upper half; apical central sinuses 5–6 mm. deep; carpel apices semiorbicular; and the endocarp supramedian. On the other hand, *P. oblatus* has the phalanges 4.7–5.1 cm. long, 2.9–3.5 cm. wide; lateral sinuses none; apical central sinuses 2–4 mm. deep; apices of the marginal carpels oblate-pyramidal; and the endocarp submedian.

The epithet is the Latin participle, *oblatus*, given the modern scientific meaning, depressed. This refers to the oblate-pyramidal carpel apices.

Pandanus somersetensis sp. nov. (sect. *Pandanus*)
Figs. 29–30

DIAGNOSIS HOLOTYPI: Arbor 5–8 m. alta 20–30 cm. diametro supra media ramosa, cortice armato cum muriculis, radicibus fulturosis 6–15 cm. longis pluribus, foliis 93 cm. longis 6.8–7.2 cm. latis coriaceis glaucis gladiformibus sed sensim diminentibus ad apicem acutum in puncto 10 cm. ex apice 7 mm. latis in base marginibus integris sed ex loco 7–10 cm. e base in uno latere cum aculeis 1.5–2.3 mm. longis 3–8 mm. distantibus crassiter subulatis stramineis adscendentibus sed in latere altero aculeis 0.5–1 mm. longis 3–15 mm. distantibus midnervio exarmato fere ubique, foliis in section mediale integris et in parte apicale marginibus integris sed nervo mediale infra cum aculeis 0.3 mm. longis paucis remotis, pedunculis ca. 25 cm.

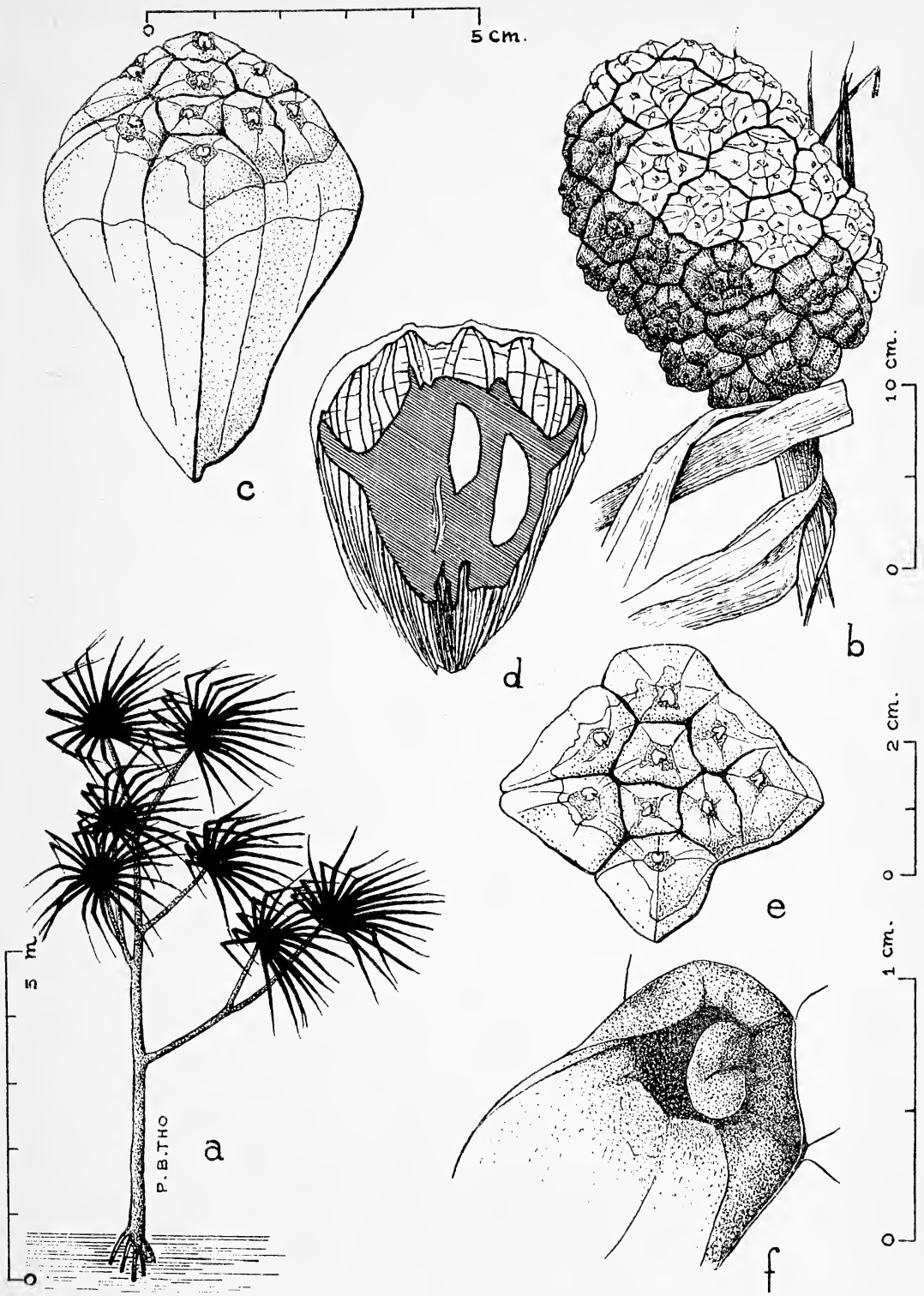

FIG. 29. *Pandanus somersetensis,* from holotype. *a,* Habit, × 1/100; *b,* syncarp, × 3/16; *c,* phalange, lateral view, × 1; *d,* phalange, apical view, × 1; *e,* apex of carpel and stigma, apical view, × 4.

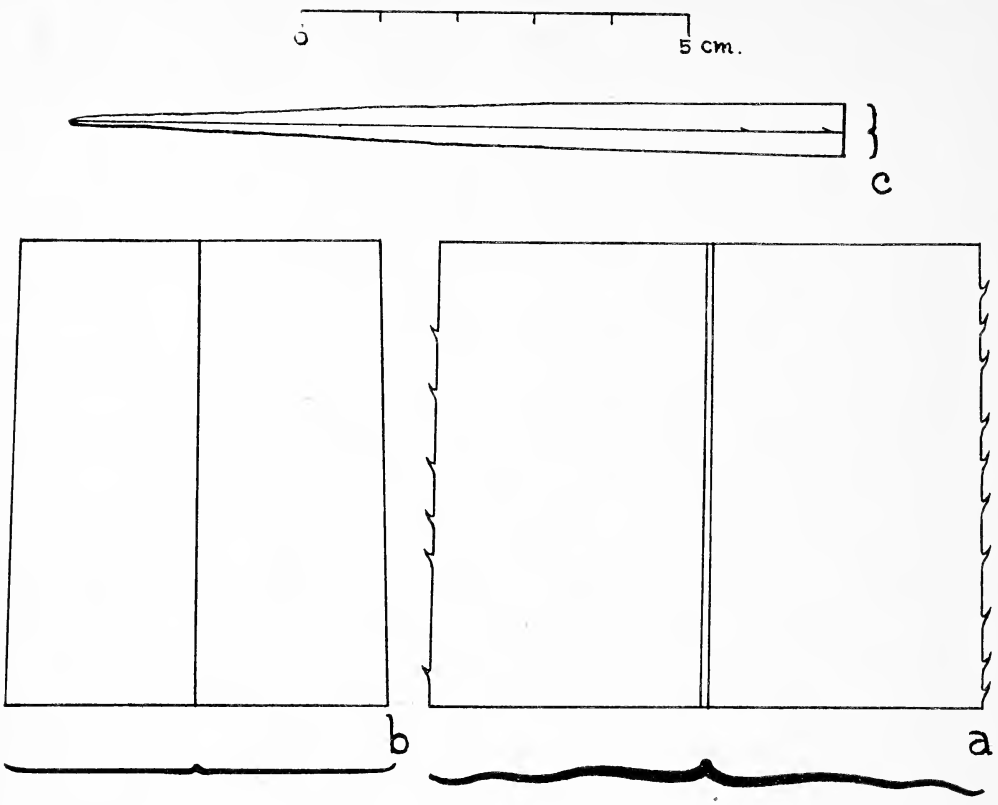

FIG. 30. *Pandanus somersetensis,* from holotype, lower side of leaf, × 1. *a,* Near base; *b,* middle; *c,* apex.

longis foliosis, syncarpiis terminalibus singularibus maximis eorum 22 cm. longis 13 cm. diametro late ellipsoideis subtriangularibus cum ca. 70 phalangibus eis 5–5.5 cm. longis 4–5.1 cm. latis 3.2–4.5 cm. crassis anguste obpyramidalibus 4–6-angulosis in sicco brunneis laevibus et sublucidis lateribus paene curvatis vel planis parte ¼ supera libera, apice lato depresse convexo, suturis lateralibus raris sed paucis et solo in parte quarta supera evidentis, suturis apicalibus centralibus 0.5–1 mm. profundis sed plerumque tam vadosis quam paene imperceptis sunt et suturis solum tessellatis, carpelis 7–9, apicibus inequalibus quod carpelis lateralibus in latere exteriore distentis sunt sed apicibus omnibus veris brunneis subaequalibus et subplanis sed eis centralibus minime depresso-conicis, stigmatibus 1.5–3 mm. longis ovato-deltoideis ad ellipticis horizontalibus centripetalibus minime elevatis, sutura proxima ad dimidiam intervallam ad basem producta, endocarpio mediale osseoso subalbo in latere 2–3 mm. crasso, seminibus 15–16 mm. longis 5 mm. diametro oblique ellipsoideis, mesocarpio supero cavernoso et cum fibris longitudinalibus crassis et membranis albis, mesocarpio infero fibroso et carnoso sed minimo.

DIAGNOSIS OF HOLOTYPE: Tree 5–8 m. tall, 20–30 cm. in diameter, branching in 2's or 3's, beginning halfway up, the crown semiorbicular; bark armed with scattered, short, sharp bosses; prop roots several, 6–15 cm. long; leaves 93 cm. long, 6.8–7.2 cm. wide, coriaceous, glaucous, sword-like but tapering gradually from the base to the acute tip, this 10 cm. down 7 mm. wide, at the very base the margins entire, but beginning 7–10.5 cm. above it having on one side ascending prickles 1.5–2.2 mm. long, 3–8 mm. apart, stout subulate, stramineous, but on the other border 0.5–1 mm. long, 3–15 mm. apart, the midrib smooth almost throughout; at the middle the margins entire; near the tip the margins entire and only the midrib below with a few remote ascending prickles 0.3 mm. long;

peduncles about 25 cm. long, leafy bracted; syncarps terminal, single, the largest 22 cm. long, 13 cm. in diameter, broadly ellipsoid, obscurely 3-angled, the color unknown, of about 70 phalanges; phalanges 5–5.5 cm. long, 4–5.1 cm. wide, 3.2–4.5 cm. thick, narrowly obpyramidal, 4–6-angled, when dried light brown, smooth and somewhat shiny, the sides gently curving or plane, free in upper ¼, the apex broad, low convex, lateral carpel sutures mostly none, but a few perceptible down ¼ way, the central apical sutures 0.5–1 mm. deep, but mostly so shallow as to be almost imperceptible and the sutures merely making a tessellate pattern; carpels 7–9, the apices somewhat unequal as the lateral ones have considerable expansion on the outer side, but the brown colored, actual apex is subequal on all and is almost flat, though the central ones have a perceptible depressed conic elevation; stigmas 1.5–3 mm. long, ovate-deltoid to elliptic, horizontal, centripetal, slightly raised, below it the proximal suture on the carpel apex from very short to ½ as long as the distance to the intercarpellary suture; endocarp median, bony, whitish, that surrounding the outer seeds 2–3 mm. thick; seeds 15–16 mm. long, 5 mm. in diameter, obliquely ellipsoid; upper mesocarp cavernous, with very stout longitudinal fibers and delicate, white, medullary membranes; lower mesocarp fibrous and fleshy, but of small extent.

HOLOTYPUS: Australia, Queensland, Cape York Peninsula, Newcastle Bay, 2½ mi. S. of Somerset, commonly on rocky coastline and beside small freshwater streams in coastal sand dune area, May 13, 1948, *L. J. Brass 18,792* (BRI).

This new species certainly belongs in the section *Pandanus,* even though the stigmas are subhorizontal. None of the published species in that section are so similar that it would be of value to state the contrasting differences.

The new epithet is geographic, indicating the type locality of the species.

Pandanus truncatus sp. nov. (sect. *Pandanus*)
Figs. 31–32

DIAGNOSIS HOLOTYPUS: Arbor 6–8 m. alta, laxe ramosa, foliis 1.43 m. longis 6 cm. latis in base coriaceis ligulatis infra minus glaucis ex base gradatim diminuentibus ad apicem subulatum in puncto 10 cm. ex apice 3 mm. latis in base exarmatis sed ex puncto 15 cm. ex base marginibus cum aculeis 1.5–2 mm. longis 3–10 mm. distantibus aciculatis rectis adscendentibus in apice brunneis, in parte mediale marginibus et midnervio exarmatis, ad apicem marginibus midnervioque infra cum serris remotis 0.2–0.3 mm. longis, syncarpio terminale singulare subpendente, pedunculo 20 cm. longo triangulare bracteato, syncarpio 18 cm. longo 13 cm. diametro late ellipsoideo cum ca. 56 phalangibus 4.5–5 cm. longis 3.1–4.1 cm. latis 2.9–3.3 cm. crassis late obovoideis, apice depresse convexo, ⅓ parte supera libera, lateribus cum 6–8 angulis majoribus et 2–3-plo angulis et vallibus minoribus in sicco pallide brunneis laevibus et lucidis, suturis lateralibus fortibus ½ vel omnia distancia extensis, sinibus centralibus apicalibus 3–4 mm. profundis angustis sinuatisque, carpellis 7–11, apicibus subaequalibus pyramidali-semiorbicularibus omnibus marginalibus et paucis centralibus cum area plana vel minime concava obscure brunnea terminale, stigmatibus centripetalibus 1–1.5 m. longis suborbicularibus vel obcordatis valde inclinatis, sutura proximali et stigmate dimidia vel omnia distancia ad vadum extensa, endocarpio mediale osseoso albo solum in parte supera extensa sed in lateribus et parte infera diminuenda in muris 0.5 mm. crassis, seminibus 23–25 mm. longis 4–6 mm. diametro ellipsoideis, mesocarpio supero pluricavernoso cum fibris validis et membranis medullosis pallidis, mesocarpio infero fibroso et carnoso sed in base toto carnoso.

DIAGNOSIS OF HOLOTYPE: Tree 6–8 m. tall, branched into a very open crown; leaves 1.43 m. long, 6 cm. wide near the base, coriaceous, ligulate, somewhat glaucous below, tapering gradually from the very base up to the subulate tip which 10 cm. down is 3 mm. wide, the base unarmed, but beginning 15 cm. up the margins with spines 1.5–2 mm. long, 3–10 mm. apart, straight acicular, ascending, brown-tipped; in the median region the margins and midrib unarmed; near the apex the margins and midrib below with a few remote serrations 0.2–0.3 mm. long; syncarp terminal, single, almost pendent, borne on a triangular, leafy bracted peduncle about 20 cm. long, the syncarp 18 cm. long, 13 cm. in diameter, broadly ellipsoid, of about 56 phalanges, these 4.5–5 cm. long, 3.1–4.1 cm. wide, 2.9–3.3 cm. thick, broadly obovoid, the

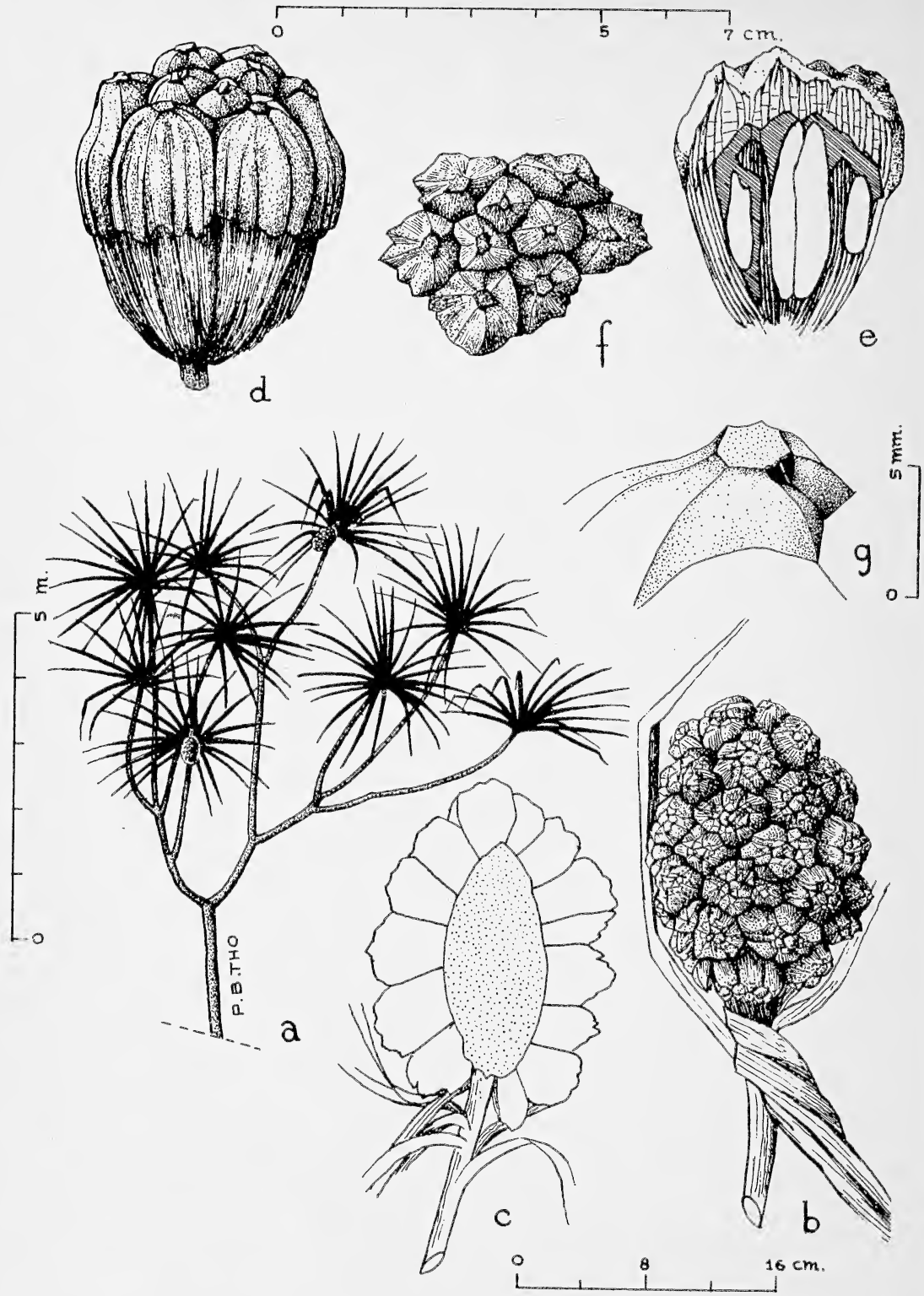

FIG. 31. *Pandanus truncatus,* from holotype. *a,* Habit, × 1/100; *b,* syncarp, × 5/18; *c,* syncarp, longitudinal section, × 5/18; *d,* phalange, lateral view, × 1; *e,* phalange, longitudinal median section, × 1; *f,* phalange, apical view, × 1; *g,* apex of carpel and stigma, oblique view, × 4.

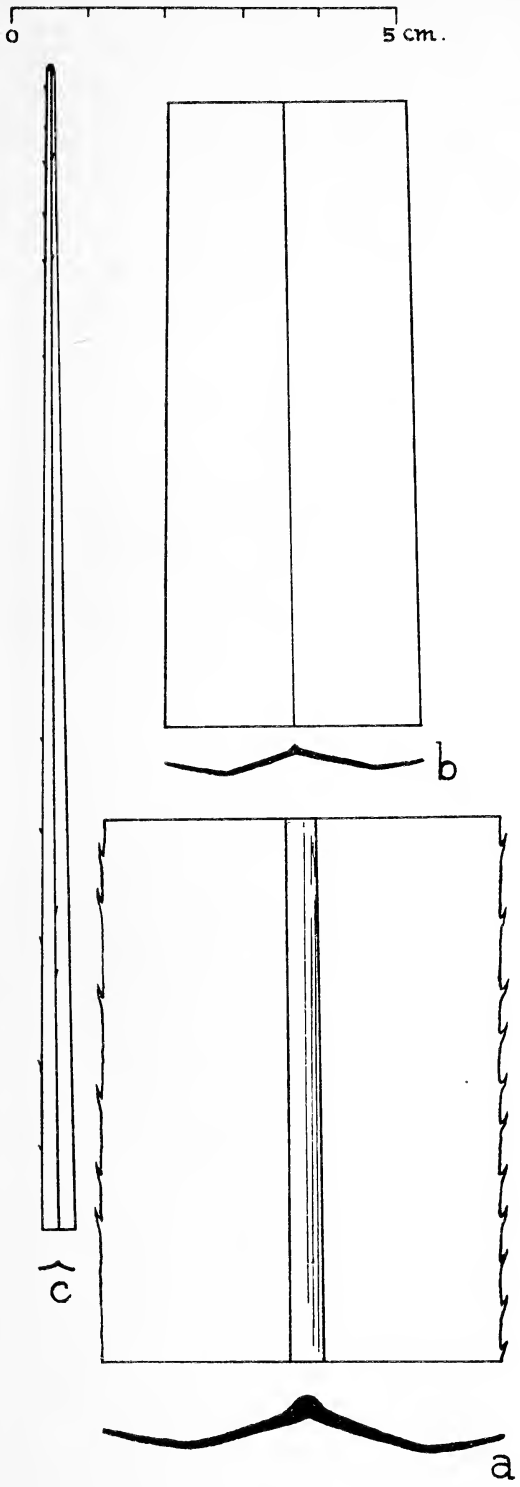

FIG. 32. *Pandanus truncatus*, from holotype, lower side of leaf, × 1. *a*, Near base; *b*, middle; *c*, apex.

apex low convex, upper ⅓ free, the sides with 6–8 major angles and with 2–3-times that number of secondary sharp ridges, so that the adjacent phalanges fit as if mortised, when dried light brown, smooth and shiny, lateral carpel sutures well marked ½ way or nearly all the way down, the central apical sinuses 3–4 mm. deep, the bottoms narrow and sinuous; carpels 7–11, the apices subequal pyramidal-semiorbicular, all the marginal and some of the central ones with a dark brown flat or slightly concave surface below the proximal edge of which is the steeply oblique, centripetal stigma 1–1.5 m. long, suborbicular to obcordate, and below it the proximal crease running ½ way or all the way to the bottom; endocarp median, bony, white, extensive only at the upper end, diminishing on the sides and lower part to thin sheets only 0.5 mm. thick; seeds 23–25 mm. long, 4–6 mm. in diameter, ellipsoid; upper mesocarp of several caverns with strong longitudinal fibers and pale medullary membranes; lower mesocarp fibrous and fleshy, but the actual base almost wholly fleshy.

HOLOTYPUS: Australia, Queensland, Cape York Peninsula, Lockerbie, 10 mi. WSW of Somerset, common and in places forming small groves on sandy soil in savanna-forest, 30 m. alt., 1948, *L. J. Brass 18,552* (BRI).

DISCUSSION: The closest relative, *P. Brookei* Martelli, has the leaves near the base with marginal teeth 2–3 mm. long; syncarp cylindric, 43 × 21.5 cm., with about 66 phalanges the sides of which are plane or gently curving; apices of the marginal carpels broad concave on a broad pyramidal base; central apical sinuses 4–6 mm. deep, the lines straight or gently curved; stigmas horizontal, 2–3 mm. long; and the endocarp 2 cm. long. On the other hand, *P. truncatus* has the leaves with marginal teeth near the base with teeth 1.5–2 mm. long; phalange sides sharply ridged and mortised with neighbors; syncarp broadly ellipsoid, 18 × 13 cm., with about 56 phalanges; apices of marginal carpels with oblique, truncate planes exterior of the stigmas; central apical sinuses 3–4 mm. deep, the lines sinuous; and the stigmas steeply inclined, 1–1.5 mm. long.

The new epithet is the Latin participle, *truncatus*, cut off, or flat ended, in allusion to the shape of the carpel apices.

Revision of the Genus *Pandanus* Stickman, Part 7
New Species from Borneo, Papua, and the Solomon Islands

HAROLD ST. JOHN[1]

THIS SEVENTH PART of the series contains descriptions of miscellaneous new species from islands in the tropical Pacific.

Pandanus Andersonii sp. nov. (sect. *Acrostigma*)

Figs. 33–34

NOM. VERN.: "surong irit."

DIAGNOSIS HOLOTYPI: Pedunculo ad 10 cm. longo 2.5 cm. diametro obtuse trigono ebracteato erecto, syncarpiis 1–3 spicatis in inflorescentia erecta 15 cm. longa evidenta, syncarpiis 11.5–14 cm. longis 13.5–14 cm. diametro late ellipsoideis vel subglobosis obtuse trigonatis cum drupis numerosissimis, drupis 35–40 mm. longis 6–7 mm. latis 5–6 mm. crassis fusiformibus 5–6-angulatis corpore 18–21 mm. longo oblongo-ellipsoideo pileo quam corporem latiore 13–17 mm. longo in stylo sensim diminuenti, parte principali brunnea ex squamis late deltoideis lucidis dense congregatis erectis ex axile perpendicularibus, drupis in fasciculis dehiscentibus, et pileis in laminis grandibus dehiscentibus, stylo 5–7 mm. longo subulato arcuato stigmatam distalem ferento, stigmate 4–5 mm. longo sublineari in fissura, endocarpio in ¼ parte infera albo cartilagineo lateribus 0.2 mm. crassis, mesocarpio apicali cavernoso ellipsoideo 8–9 mm. longo, mesocarpio basali 5 mm. longo fibroso et carnoso.

DESCRIPTION OF ALL SPECIMENS EXAMINED: "Roots ramify below water table; rhizome at surface level." Stem 20–25 cm. long, 1.2 cm. in diameter, assurgent, forking and forming dense thickets; leaves 2.6–6.8 m. long, 2.6–2.8 cm. wide, coriaceous, ligulate, 3-nerved and plicate, M-shaped in cross section, the under side slightly paler, abruptly narrowed to the heavy subulate tip which 10 cm. down is 13 mm. wide, the base entire and amplexicaul, but beginning 9 cm. up the margins with stout serrations 2–2.5 mm. long, 5–13 mm. apart, pale; the midrib below beginning 7–8 cm. up with reflexed prickles 4–6 mm. long, 7–17 mm. apart, stout arcuate subulate, becoming brown; at midsection the margins with serrations 1–1.5 mm. long, 5–10 mm. apart, pale below, the tips brownish; the midrib unarmed; near the tip the margins and midrib below with serrations 0.5–1 mm. long, the marginal 2–3 mm. apart, those of the midrib 3–8 mm. apart; on the upper side the two secondary ribs with serrations about 0.5 mm. long, 9–30 mm. apart; pistillate inflorescence ascending, not concealed; peduncle up to 10 cm. long, and 2.5 cm. in diameter, obtusely trigonous, bractless, erect; heads solitary or 2–3 in a spike 15 cm. long; syncarps 11.5–14 cm. long, 13.5–14 cm. in diameter, broadly ellipsoid to subglobose, obtusely trigonous, bearing very numerous drupes (several hundred); drupes 35–40 mm. long. 6–7 mm. wide, 5–6 mm. thick, fusiform, 5–6-angled, the body 18–21 mm. long, oblong-ellipsoid; the pileus the widest part, lance conic, 13–17 mm. long, narrowing gradually into the style, the body appearing rough and brown, from the dense outgrowth of closely packed, brown, shining (perhaps viscid) broad triangular scales, erect from the surface and all perpendicular to the drupe axis; drupes shedding in bundles and the pileuses cohering, early shedding in great sheets; style 5–7 mm. long, subulate, arcuate, glabrous, bearing a distal stigma 4–5 mm. long, almost linear in an open crack on the curved style; endocarp in lower ¼, white, cartilaginous, the walls 0.2 mm. thick; apical mesocarp an empty cavern, 8–9 mm. long, ellipsoid; basal mesocarp 5 mm. long, fibrous and fleshy.

HOLOTYPUS: Sarawak, Lawas District, Kayangeran Forest Reserve, in "Sempilor" (*Dacrydium Beccarii* var. *subelatum*) forest, 10 ft. alt., Nov. 1960, *J. A. R. Anderson* (fruit only) (SARF).

[1] Botanist, B. P. Bishop Museum, Honolulu, Hawaii.
Manuscript received September 13, 1960.

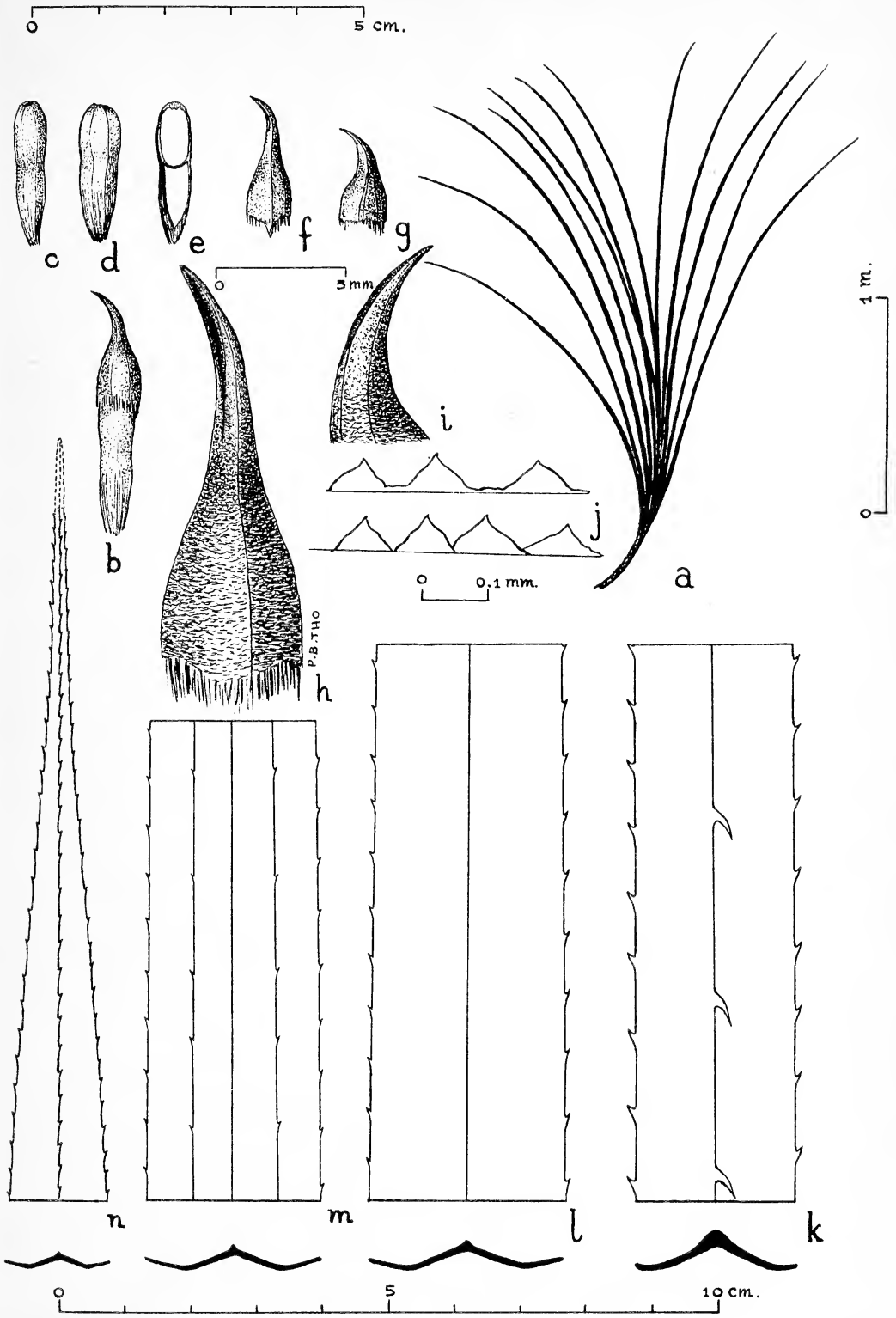

FIG. 33. *Pandanus Andersonii* St. John, from holotype. *a,* Habit, × 1/40; *b,* drupe, lateral view, × 1; *c, d,* drupes after shedding pileus, lateral view, × 1; *e,* drupe, longitudinal median section, × 1; *f, g,* pileus, lateral view, × 1; *h,* pileus and stigma, lateral view, × 4; *i,* style and stigma of basal drupe, lateral view, × 4; *j,* scales of pileus, basal view, × 100; *k,* base of leaf, lower side, × 1; *l,* leaf middle, lower side, × 1; *m,* leaf, slightly beyond the middle, upper side, × 1; *n,* leaf apex, lower side, × 1.

SPECIMENS EXAMINED: Sarawak, Loba Kabang Protected Forest, abundant, ground flora in "alan" (*Shorea albida*) type forest, found in wetter areas and associated with "bakong" (*Hanguana malayana*), May 16, 1954, *J. A. R. Anderson S.2,815* (SARF).

DISCUSSION: *P. Andersonii* is a member of the section *Acrostigma* and there one finds its closest relative, *P. brevifolius* Martelli of Borneo. This has the syncarp solitary, 5 cm. long, 4 cm. in diameter; drupes 15–16 mm. long, 3 mm. wide; pileus abruptly contracted to the style; and the endocarp in the lower ⅓. On the other hand, *P. Andersonii* St. John has the syncarps

FIG. 34. *Pandanus Andersonii* St. John, in foreground, in peat swamp forest of *Shorea albida,* Baram River, Sarawak. (Photo by J. A. R. Anderson.)

1–3 in a spike and 11.5–14 cm. long, 13.5–14 cm. in diameter; drupes 35–40 mm. long, 6–7 mm. wide; pileus tapering into the style; and the endocarp in the lower ¼.

The new species is named in honor of its collector, Mr. J. A. R. Anderson, Forest Research Officer of the Sarawak government.

Pandanus fruticosus sp. nov. (sect. *Acrostigma*)
Figs. 35–36

DIAGNOSIS HOLOTYPI: Frutex 15.5 m. altus ramosus, ramulis foliosis 6–9 cm. diametro, cortice rubrescenti-brunneo lucido cum cicatricibus pallidis cinctis, foliis 51–58 cm. longis 8–10 mm. latis subcoriaceis ligulatis M-formatis longe diminuentibus in apice subulato 10 cm. ex apice 3.5 mm. lato, marginibus in basi integris sed ex 4 cm. marginibus cum dentibus validis subulatis 0.5–1.3 mm. longis 1–3 mm. distantibus nigris in 45° adscendentibus, midnervio exarmato, marginibus in sectio mediale cum serris nigris 0.5 mm. longis 1–2 mm. distantibus, midnervio infra cum serris nigris 2–6 mm. longis 2–6 mm. distantibus, circa apicem marginibus et midnervio infra cum serris acutis 0.4–0.5 mm. longis 0.5–1.5 mm. distantibus, inflorescentia foeminea solitaria terminale cum bracteis plurimis 16 mm. latis amplectentibus, syncarpio subsessile 3 cm. longo 2 cm. diametro ellipsoideo, drupis multis 9–10 mm. longis 2–2.5 mm. diametro fusiformis, corpore 4–5 mm. longo, pileo obliquiter conico 4 (–5) mm. longo ad stylum tenuato, stylo subulato cum linea stigmata proxima 2.5–3 mm. longa, endocarpio supramediale lateribus 0.1 mm. crassis pallidis, semine 3.5 mm. longo 1.6 mm. diametro late elliptico, mesocarpio infero cavernoso.

DESCRIPTION OF HOLOTYPE: Shrub 15.5 m. tall, forking; leafy branchlets 6–9 cm. in diameter, the bark reddish brown, shining, ringed by pale leaf scars; leaves 51–58 cm. long, 8–10 mm. wide, subcoriaceous, ligulate, M-shaped in cross section, long tapering to a subulate apex which at 10 cm. back from the tip is 3.5 mm. wide, margins at the very base entire, but from about 4 cm. up the margins with stout subulate teeth, 0.5–1.3 mm. long, 1–3 mm. apart, wholly black, ascending at 45°, the midrib unarmed; at the midsection the margins black serrate, the teeth 0.5 mm. long, 1–2 mm. apart, the midrib below appressed, subulate, black serrate, the teeth 2–6 mm. apart; near the apex the margins and midrib below sharply serrate, the teeth 0.4–0.5 mm. long, 0.5–1.5 mm. apart; pistillate inflorescence solitary, terminal, surrounded by several bracteal leaves 16 mm. wide around the spike, but otherwise like the normal foliage leaves; syncarp subsessile 3 cm. long, 2 cm. in diameter, ellipsoid, with numerous drupes; drupes 9–10 mm. long, 2–2.5 mm. in diameter, fusiform, the body 4–5 mm. long, the pileus oblique conic, 4 (–5) mm. long, tapering into the subulate style which is linear stigmatic for 2.5–3 mm. on the proximal side; endocarp from middle to apex of body, the wall 0.1 mm. thick, pale; seed 3.5 mm. long, 1.6 mm. in diameter, broady ellipsoid; lower mesocarp cavernous.

HOLOTYPUS: North Borneo, Keningau District, 76½ mi. on path from Tenom to Ranau (8½ mi. NE. of Tambunan), 2,100 ft. alt., Aug. 27, 1954, *G. H. S. Wood & J. Wyatt-Smith A 4,430* (BRI).

DISCUSSION: The new species *P. fruticosus* is in the section *Acrostigma*. Its nearest relative is the Malayan species *P. aurantiacus* Ridl. which has the leaves 3.8 cm. wide; inflorescence of 5 heads; syncarp 6.2 cm. long, 2.5 cm. in diameter; drupes 18 mm. long; and the endocarp 12 mm. long. On the other hand, *P. fruticosus* has leaves 8–10 mm. wide; the syncarp solitary; drupes 9–10 mm. long; and the endocarp 3.7 mm. long.

The new epithet is the Latin adjective, *fruticosus*, shrubby, given with reference to the plant habit.

Pandanus ruber *sp.* nov. (sect. *Microstigma*)
Figs. 37–38

DIAGNOSIS HOLOTYPI: Arbor 3–5 m. alta ramosa, trunco cum aculeis adscendentibus armato, radicibus fulturosis paucis aculeatis, foliis 172 cm. longis 10.2 cm. latis coriaceis in sectio M-formatis ligulatis acutis in sectio 10 cm. ex apice 4 cm. latis in base integris sed ex puncto 9 cm. e base cum aculeis 1–1.6 mm. longis 2–7 mm. distantibus salientibus stramineis, midnervio inerme, in sectio mediale marginibus cum aculeis 1–1.5 mm. longis 3–6 mm. distanti-

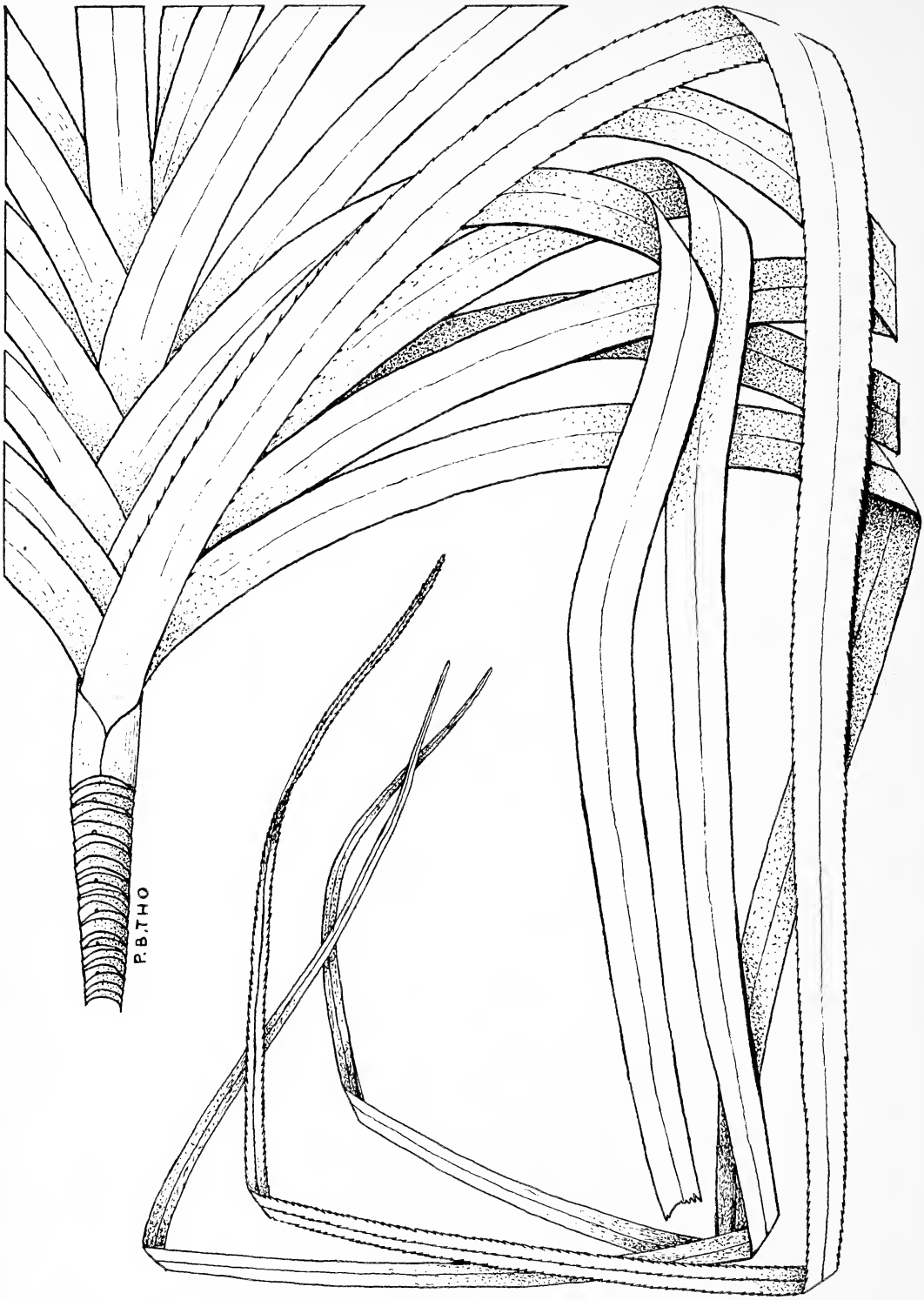

FIG. 35. *Pandanus fruticosus* St. John, from holotype. Habit, × 1.

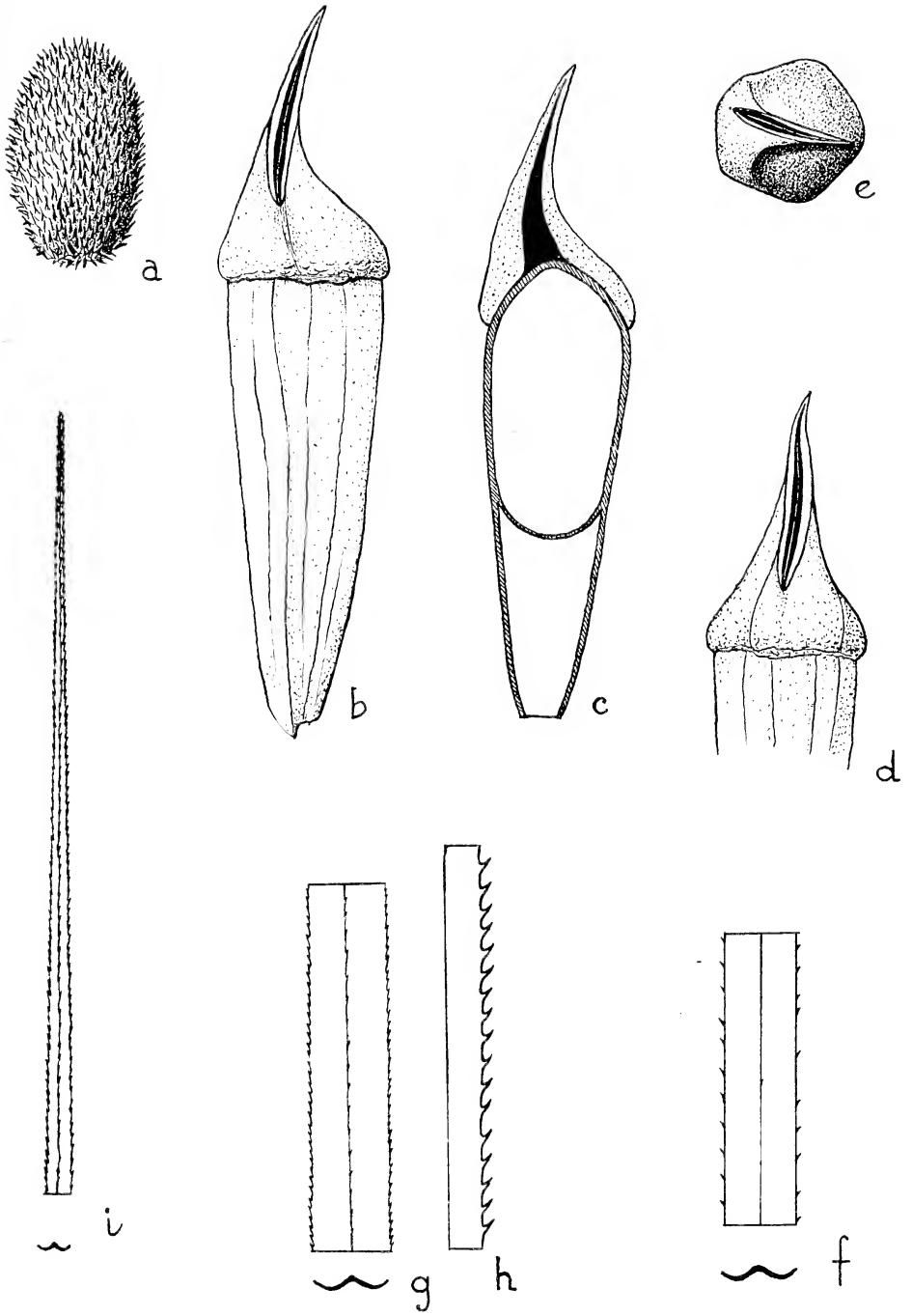

FIG. 36. *Pandanus fruticosus* St. John, from holotype. *a*, Syncarp, lateral view, × 1; *b*, drupe, lateral view, × 10; *c*, drupe, longitudinal median section, × 10; *d*, pileus and stigma, lateral view, × 10; *e*, pileus and stigma, apical view, × 10; *f*, leaf base, lower side, × 1; *g*, leaf middle, lower side, × 1; *h*, leaf margin, at middle, × 10; *i*, leaf apex, lower side, × 1.

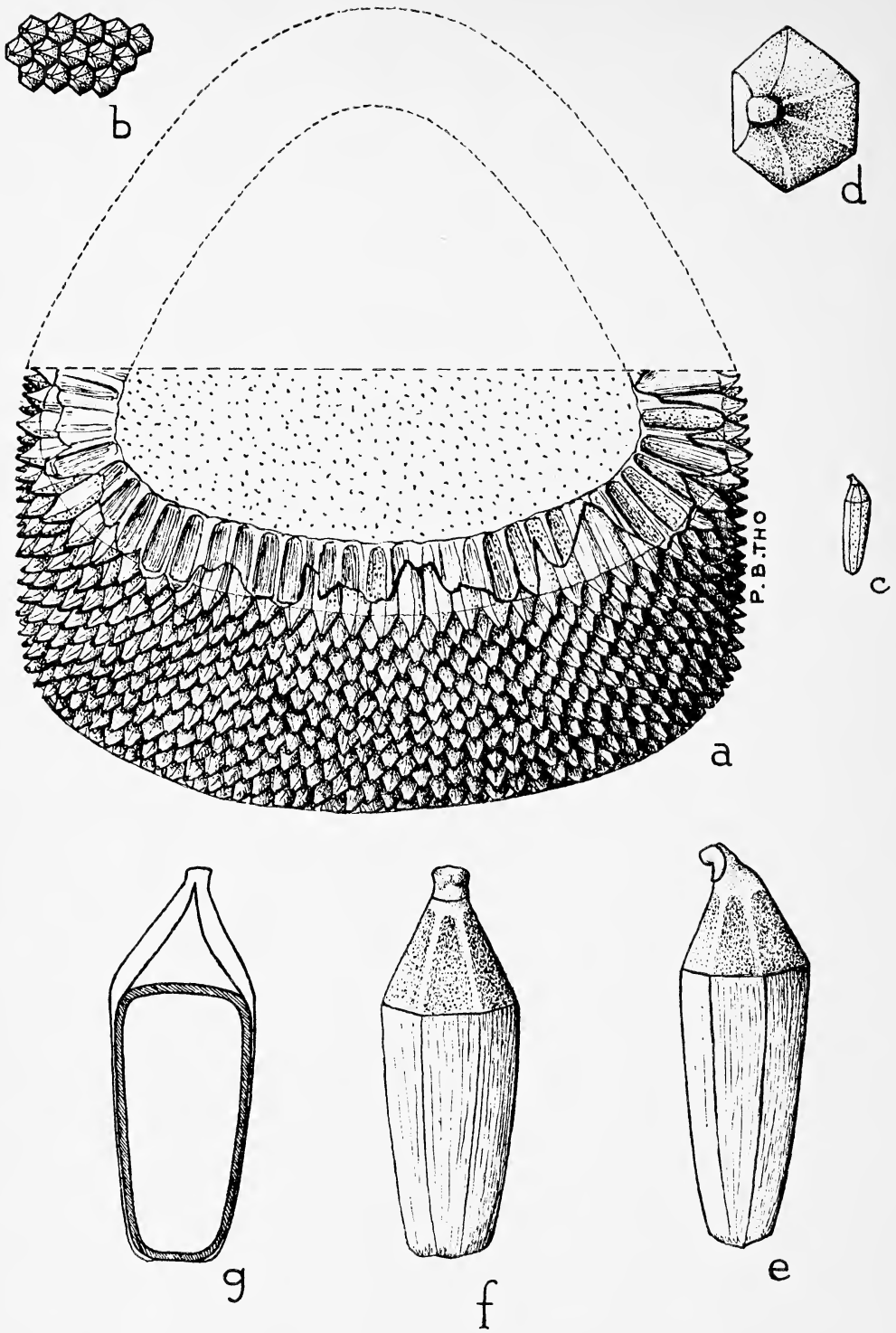

FIG. 37. *Pandanus ruber* St. John, from holotype. *a,* Syncarp, median section, × 1; *b,* drupes, apical view, × 1; *c,* drupe, lateral view, × 1; *d,* drupe, apical view, × 4; *e, f,* drupes, lateral view, × 4; *g,* drupe, longitudinal median section, × 4.

bus proxime adpresse-adscendentibus, midnervio cum aculeis 0.3–1 mm. longis 3–11 mm. distantibus valide aciculatis adpresse adscendentibus subbrunneis, proxime apice marginibus unicevel duplo-serratis serris 1.5–2.1 mm. longis 2–5 mm. distantibus stramineis, supra nervis secundariis cum aculeis paucis eis 0.8–1 mm. longis, infra nervo mediale saliente et cum aculeis simultantibus 1.5–2 mm. longis 3–10 mm. distantibus, syncarpiis solitariis plerumque 42 cm. longis 10.5 cm. diametro cylindricis sed subtriangulatis, receptaculo aurantiaco-rubro, drupis numerosissimis in sectio mediale 13–15 mm. longis 3–4.5 mm. latis 2.5–3 mm. crassis unicarpellatis obscure rubris 4–6-angulatis parte ¼ supera libera, pileo 3–4 mm. longo anguste pyramidale asymmetrico et arcuato corpore oblongo in base subcuneato, stigmatibus 0.8–1.5 mm. longis et latis suborbicularibus brunneis verticalibus proximalibus infra petaso terminale, endocarpio basale 9 mm. longo osseoso obscure brunneo lucido 0.4–0.5 mm. crasso, mesocarpio apicale caverno unico.

DIAGNOSIS OF HOLOTYPE: Tree, 3–5 m. tall, branched; trunk and branches armed with upturned prickles; prop roots few, prickly; leaves 172 cm. long, 10.2 cm. wide, coriaceous, M-shaped in cross section, ligulate, acute, 4 cm. wide at 10 cm. from the tip, at the very base the margins entire, but from 9 cm. up prickly, the prickles 1–1.6 mm. long, 2–7 mm. apart, spreading, straw-colored, the nearby midrib unarmed; at the middle point the margins with prickles 1–1.5 mm. long, 3–6 mm. apart, closely appressed ascending, those of the nearby midrib 0.3–1 mm. long, 3–11 mm. apart, stout acicular appressed ascending, brownish near the tip the margin simply or doubly subulate-serrate, the teeth 1.5–2.1 mm. long, 2–5 mm. apart, straw-colored, above the ribs of the two secondary pleats with a few ascending prickles 0.8–1 mm. long, below the salient midrib with similar prickles 1.5–2 mm. long, 3–10 mm. apart; syncarps solitary, averaging 42 cm. long, 10.5 cm. in diameter, cylindric but somewhat 3-sided; receptacle, orange-red; with myriad drupes, those at midsection 13–15 mm. long, 3–4.5 mm. wide, 2.5–3 mm. thick, 1-celled, dark red, 4–6-angled, upper ¼ free, the pileus 3–4 mm. long, narrowly pyramidal, asymmetric and arcuate to the apex, body almost oblong, but slightly cuneate below; stigmas 0.8–1.5 mm. long and wide, suborbicular, brown, vertical on proximal side of apex, below the apical cap; endocarp basal, 9 mm. long, bony, dark brown, shiny, the walls 0.4–0.5 mm. thick; apical mesocarp a single cavern.

HOLOTYPUS: Papua, Central Division, Bella Vista, 1,450 m. alt., planted by the natives in gullies and ravines close to their gardens, Nov. 1933, *L. J. Brass 5,463* (BRI); and isotype (A).

DISCUSSION: The closest relative is *P. Hollrungii* Warb. of Deutsch Neu-Guinea, now Australian New Guinea. It differs by having: the leaves 2.5 m. long, 5 cm. wide; syncarp 35 × 4–7 cm., sessile, spathe-surrounded; drupes 11–13 mm. long, 2.5–3 mm. wide, the apex semi-orbicular-pyramidal; stigmas apical, subhorizontal, 1.5 mm. wide; and the endocarp slightly submedian. *P. ruber* differs by having: the leaves 1.7 m. long, 10.2 cm. wide; syncarp 42 × 10.5 cm.; drupes 13–15 mm. long, 3–4 mm. wide, 3 mm. thick, the apex narrowly pyramidal, asymmetric and arcuate; stigmas 0.8–1.5 mm. wide, vertical on proximal side below overhanging apical cap; and the endocarp basal.

The collector recorded that, "the leaves of mature trees always much damaged by insects...." Also that the trees were cultivated. It is doubtless also wild in the forest. The several similar species with cylindric, red syncarps yield on boiling a fruit sauce important in the diet of the New Guinea natives.

This plant was identified as *P. conoideus* Lam. by Merrill and Perry (Journ. Arn. Arb. 20: 175, 1939). Lamarck's species is similar in its subterminal stigmas, but the drupes are 16 mm. long, the pileus is broader, and the endocarp is only submedia, and the leaves are narrower and with horrid spines. It is based on *P. ceramicus* Rumph (1743) from Amboina, Ceram, and the Indonesian islands.

The epithet, *ruber*, is the Latin adjective meaning red, here chosen because of the red color of the fruits.

Pandanus yuleensis sp. nov. (sect. *Pandanus*)
Figs. 39–40

DIAGNOSIS HOLOTYPI: Frutex ad 6.6 m. alta, cortice radicibus crassis adscendentibus ad 12

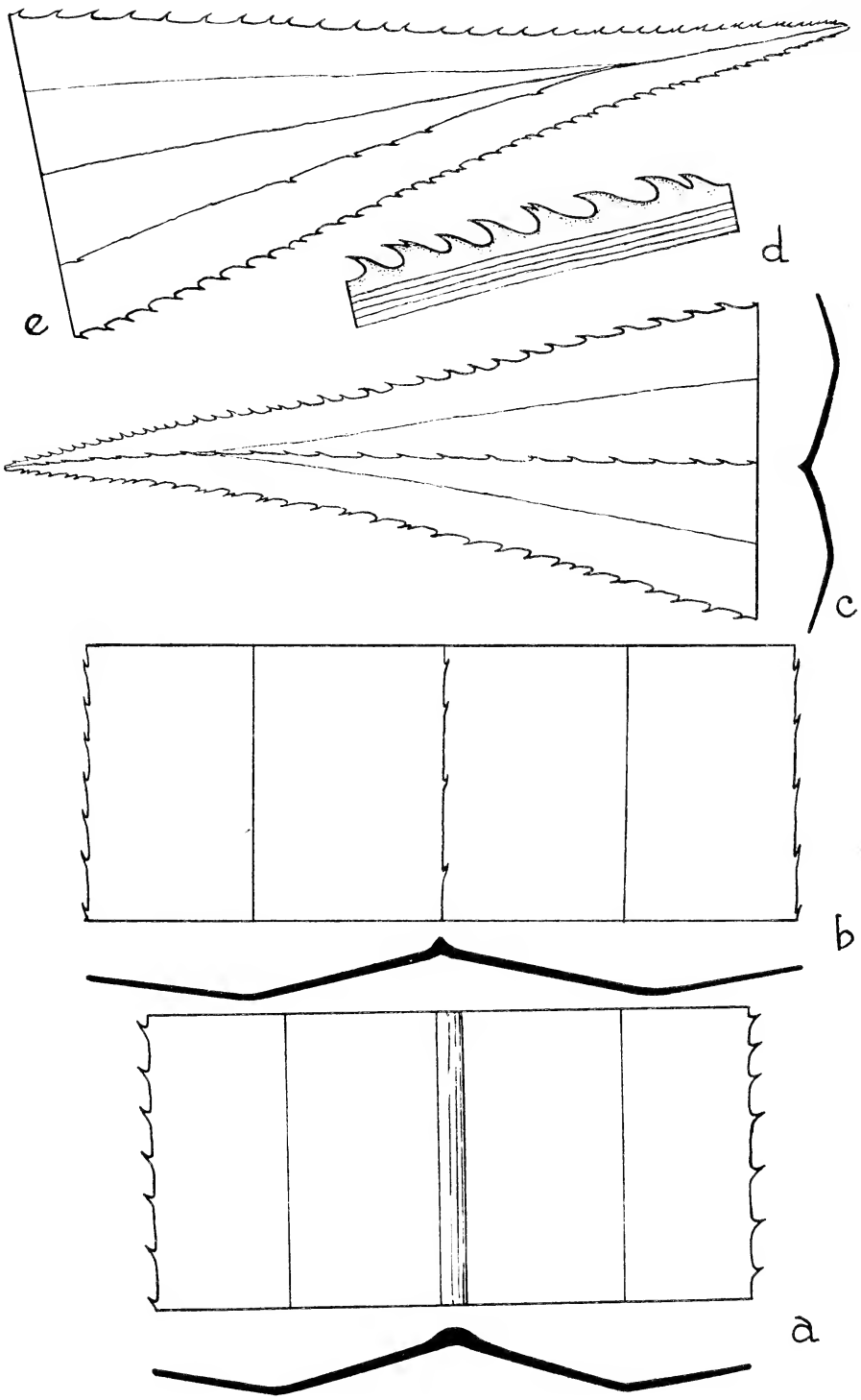

FIG. 38. *Pandanus ruber* St. John, from holotype. *a,* Leaf base, lower side, × 1; *b,* leaf middle, lower side, × 1; *c,* leaf apex, lower side, × 1; *d,* leaf margin, near apex, × 3; *e,* leaf apex, upper side, × 1.

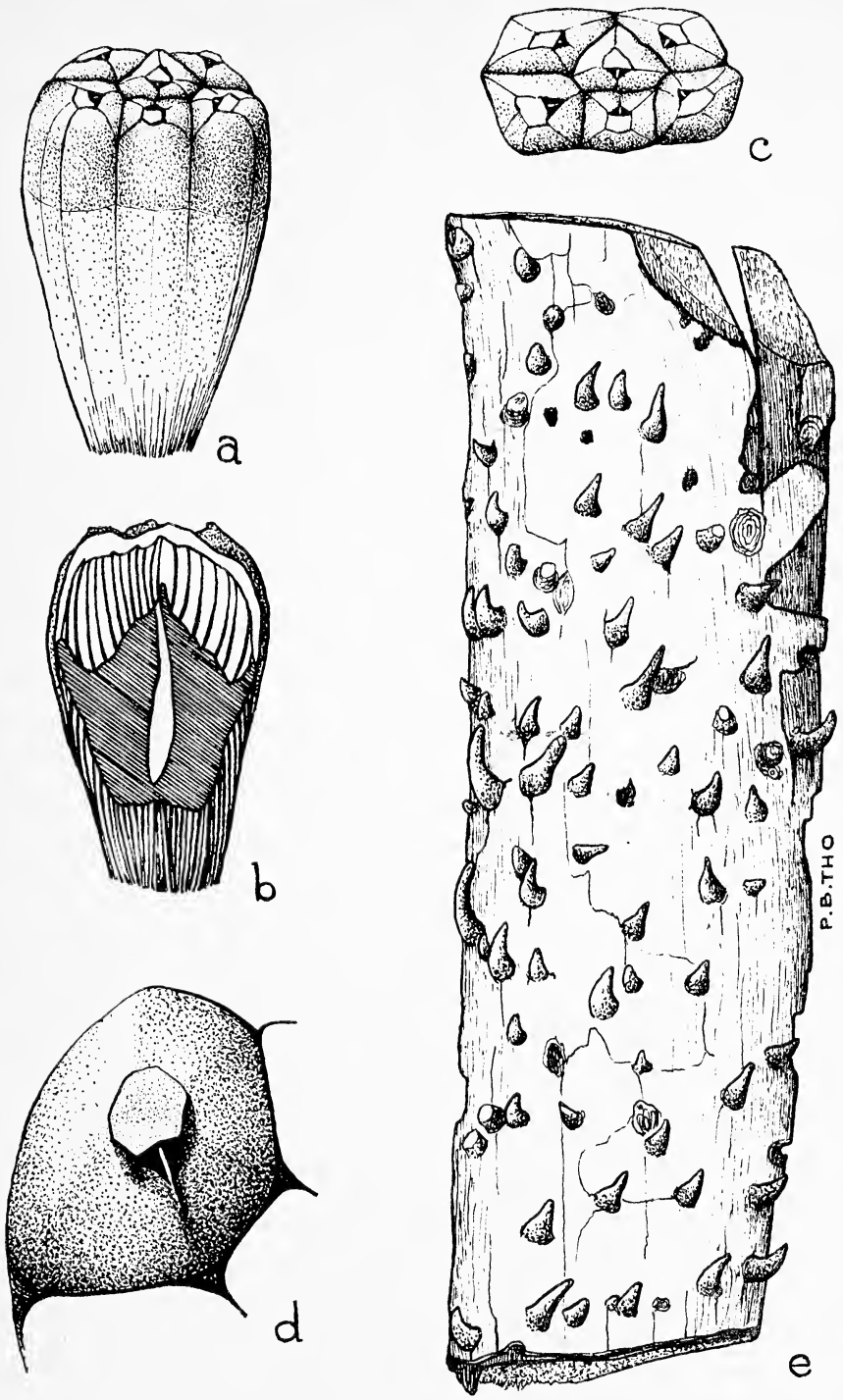

FIG. 39. *Pandanus yuleensis* St. John, from holotype. *a*, Phalange, lateral view, × 1; *b*, phalange, longitudinal median view, × 1; *c*, phalange, apical view, × 1; *d*, carpel, apical view, × 3; *e*, stem with ascending rootlets, lateral view, × 1.

mm. longis 3–10 mm. distantibus obtectis, foliis 1.6 m, longis 5.3 cm. latis gladiformis vel ligulatis sed paulatim ex base in apice longo subulato diminuentibus coriaceis in sectio transverso late M-formatis griseo-viridibus infra apparente glaucis apice deltoideo et 10 cm. ex puncto 1 mm. lato in base marginibus integris sed ex puncto 16 cm. e base cum dentibus 1.5–2 mm. longis 3–12 mm. distantibus subulatis paene curvatis in base brunneis midnervio inerme, in medio in uno latere cum dentibus 1–1.5 mm. longis 3–15 mm. distantibus adpresse adscendentibus in puncto brunneis, latere altero inerme, midnervio infra cum dentibus 0.3 mm. longis 10–30 mm. distantibus paucis brunneis validis subulatis adpresse adscendentibus, ad apicem marginibus midnervioque infra cum serris paucis 0.2 mm. longis remotis brunneis, syncarpiis scilicet terminalibus solitariisque griseo-viridibus ad 12.5 cm. diametro, phalangibus 4.4–4.7 cm. longis 2.2–3 cm. latis 1.9–2 cm. crassis late cuneatis apice subconvexo vel truncato compressis parte ⅓ supera libera lateribus 5–6-angulosis subcurvatis vel paene planis laevibus lucidis in sicco brunneis, suturis lateralibus nullis, sinibus apicalibus centralibus 3–3.5 mm. profundis, carpellis 4–6 apicibus subaequalibus conico-suborbicularibus eis marginalibus plerumque cum petaso truncato parvo et sub margine proximo eo stigma est, stigmatibus 1–2 mm. longis ovalibus vel obdeltoideis sillonatis centripetalibus, sutura proxima ex stigmate dimidia vel omnina distancia ad vadum extento, endocarpio mediale 25–27 mm. longo osseoso obscure brunneo lateribus 2.5–8 mm. crassis, seminibus 15–20 mm. longis 4 mm. diametro, mesocarpio apicale cavernoso cum fibris longitudinalibus et membranis medullosis, mesocarpio basale fibroso et carnoso.

DESCRIPTION OF ALL SPECIMENS EXAMINED: Tree up to 6.6 m. tall; bark gray, with abundant ascending, stout, adventitious roots up to 12 mm. in length but having no further development, placed 3–10 mm. apart; leaves 1.6–1.96 m. long, 5.3–6 cm. wide, sword-shaped or ligulate but tapering gradually from the base to the long subulate tip, coriaceous, in section broad M-shaped, gray-green, below apparently somewhat glaucous, the apex triangular and 10 cm. back only 1 mm. wide, at base the margins entire, but

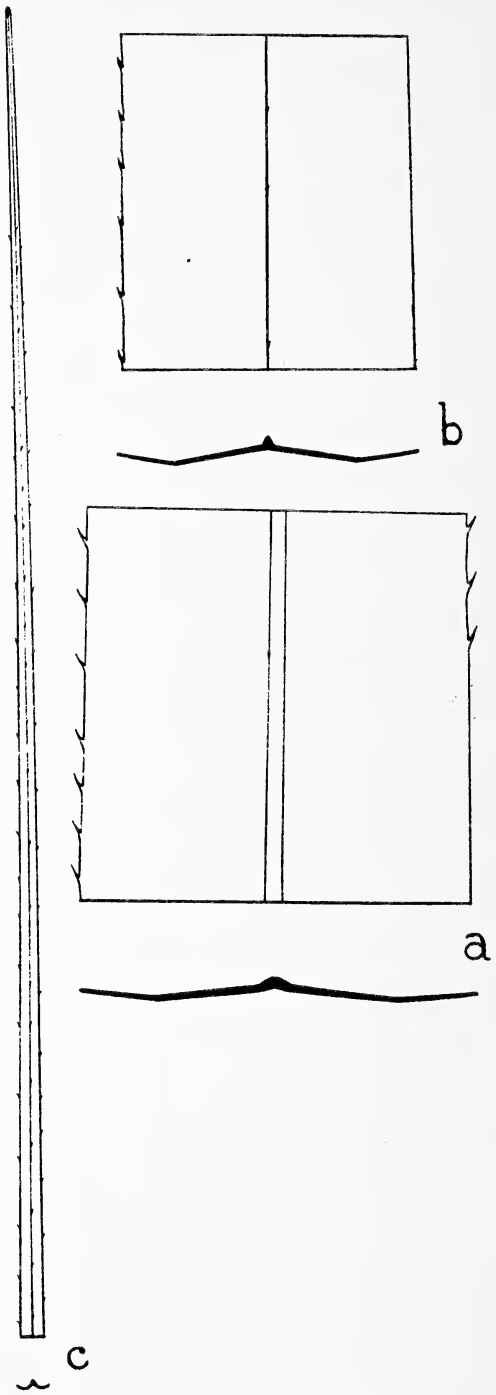

FIG. 40. *Pandanus yuleensis* St. John, from holotype. *a*, Leaf base, lower side, × 1; *b*, leaf middle, lower side, × 1; *c*, leaf apex, lower side, × 1.

beginning 10–16 cm. up, with teeth 1.5–2 mm. long, 3–12 mm. apart, subulate, gently curved, brown based, the midrib unarmed; at the middle with teeth on one side 1–1.5 mm. long, 3–15 mm. apart, brown tipped, subulate, appressed ascending, but the other margin unarmed, the adjacent midrib below with a few teeth 0.3 mm. long, 10–30 mm. apart, brown, stout subulate, appressed ascending; near the apex the margins and midrib below with a few, remote, brown serrations 0.2 mm. long; syncarps probably terminal and solitary, "gray green, up to 12.5 cm. in diameter," phalanges 4.4–4.7 cm. long, 2.2–3 cm. wide, 1.9–2 cm. thick, broad cuneate, the apex subconvex or truncate, compressed, upper ⅓ free, the sides 5–6-angled, gently curving or nearly plane, smooth, shining, when dried brown, lateral carpel sutures none, central apical sinuses 3–3.5 mm. deep; carpels 4–6, the apices subequal, conic-semiorbicular, the marginal ones usually with a small truncate cap in the proximal lee of which is the inclined stigma, stigmas 1–2 mm. long, oval to obdeltoid, creased, centripetal, below it the proximal crease on the carpel apex running from half way to all the way to the bottom; endocarp median, 25–27 mm. long, bony, dark brown, the lateral walls 2.5–8 mm. thick; seeds 15–20 mm. long, 4 mm. in diameter; apical mesocarp cavernous, traversed by longitudinal fibers and with delicate medullary membranes; basal mesocarp fibrous and fleshy.

Papua: Yule Island, Jan. 16, 1955, *J. S. Womersley & N. W. Simmonds 5,099* (BRI).

SPECIMENS EXAMINED: Papua, Yule I., July/Aug., 1918, *C. T. White 770* (BRI), consisting of one leaf only.

DISCUSSION: The most similar kind is *P. odoratissimus* L. f. var. *novo-caledonicus* (Martelli) St. John, which has the phalanges 5.5 cm. long, the upper half free; carpels 7–9, the outer 2–3-times the larger; apical central sinuses 2–3.5 mm. deep; stigmas apical, horizontal; and the endocarp ⅓ the length of the phalange. On the contrary, *P. yuleensis* has the phalanges 4.4–4.7 cm. long, the upper third free; carpels 4–6, subequal; apical central sinuses 3–3.5 mm. deep; stigmas steeply oblique, placed below the truncate apex; and the endocarp more than half the length of the phalange.

The new specific epithet is an adjective made from the name of the type locality, Yule, by adding the Latin place suffix, *-ensis.*

Pandanus magnicavernosus sp. nov. (sect. *Mammillarisia*)
Figs. 41–42

DIAGNOSIS HOLOTYPI: Arbor 8 m. alta erecta ramosa cum radicibus fulturosis, foliis 1.8–1.9 m. longis 9.5–10 cm. latis pallide viridibus molliter subcoriaceis subplanis in base midnervioque luteo-brunneis midnervio et nervis binis secundariis fortibus sed dentis innoxis apice acuto base paene dilatata et cum marginibus membranaceis per 25 cm. inermibus, marginibus ultra cum serris fortibus 1.5–2 mm. longis 3–10 mm. distantibus stramineis sed apicibus brunneis, midnervio inerme, in sectio mediale marginibus cum serris 0.5 mm. longis 2–10 mm. distantibus subulatis valde adpressis, midnervio infra cum aculeis simulantibus subulatis sed fortioribus et paene brevioribus, nervis secundariis inermibus, ad apicem marginibus cum serris subulatis 0.5–0.9 mm. longis 1–2 mm. distantibus pallidis adscendente adpressis, nervis secundariis supra scabris cum serris minutis irregularibus adscendentibus, midnervio infra cum aculeis 0.3–1 mm. longis subulatis adscendentibus aggregatis, pedunculis 90 cm. longis gracilibus triangularibus, syncarpio solitario penduloso 24 cm. diametro globoso glauco, phalangibus 2–3 (rare 1)-carpellatis numerosis 7.5–8.5 cm. longis 17–35 mm. latis 14–21 mm. crassis cuneiformis 5–7-angulosis carnosis parte supera 1/6 libera apice depresse conico plurianguloso cum 1–3 extremitatibus, sinibus apicalibus centralibus 1–2 mm. profundis, stigmatibus 1.5–2 mm. longis cordatis apicalibus sulcatis quando binis centripetalibus quando tribus eo centrali ad laterem dirigito, lateribus phalangiorum planis, endocarpio in tertia infera 24–30 mm. longo osseoso pallide brunneo lateribus 3–4 mm. crassis, seminibus 10–12 mm. longis 3–4 mm. diametro ellipsoideis, mesocarpio supero cavernam unical dimidiam quam longam quam syncarpiam formante sed sectio breve cum fibris et membranis medullosis, mesocarpio infero fibroso et carnoso.

DIAGNOSIS OF HOLOTYPE: "Tree, 8 m. tall, erect, branched near top; trunk supported on

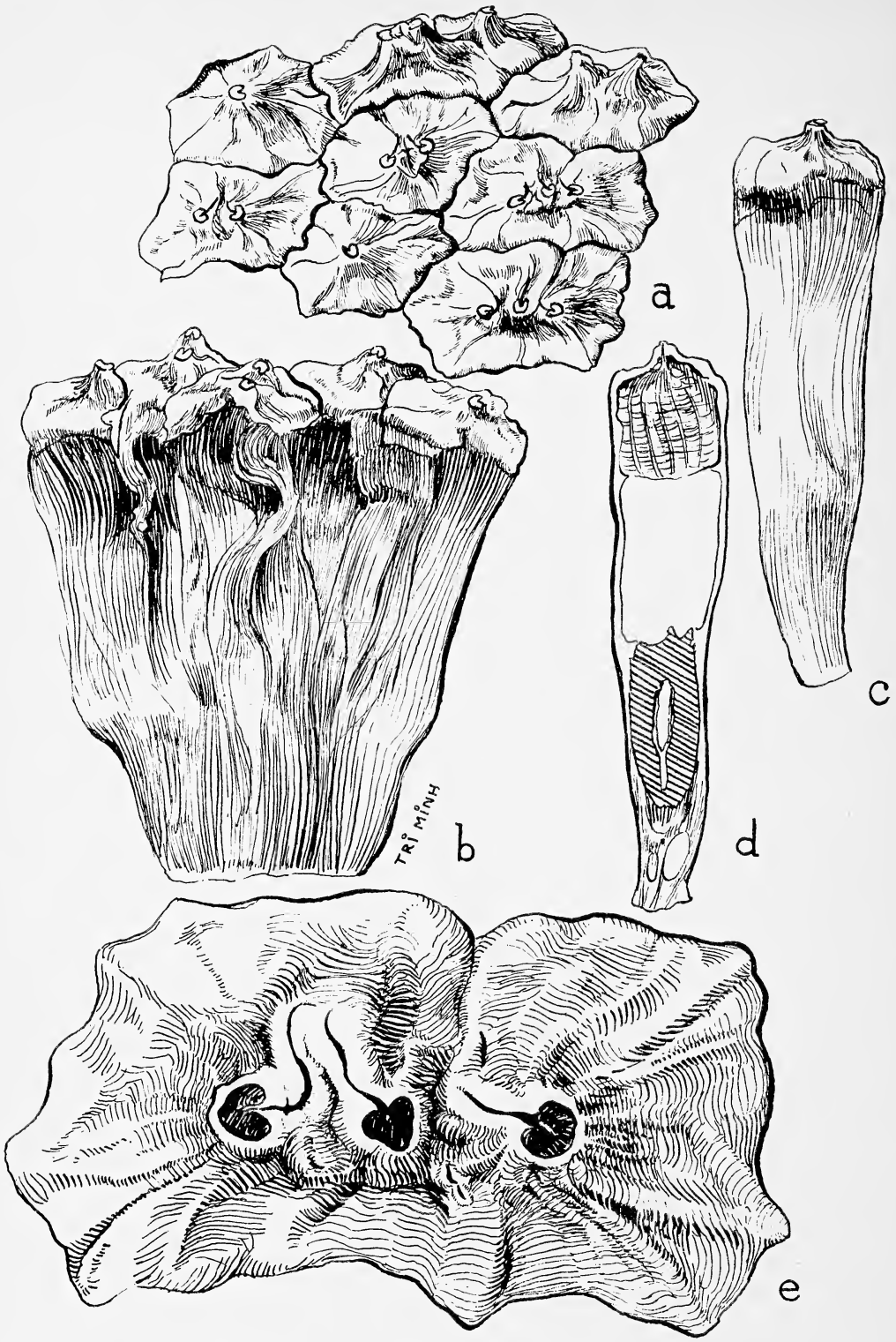

FIG. 41. *Pandanus magnicavernosus* St. John, from holotype. *a,* Phalanges, apical view, × 1; *b,* phalanges, lateral view, × 1; *c,* phalange, lateral view, × 1; *d,* phalange, longitudinal median section, × 1; *e,* phalange and stigmas, apical view, × 4.

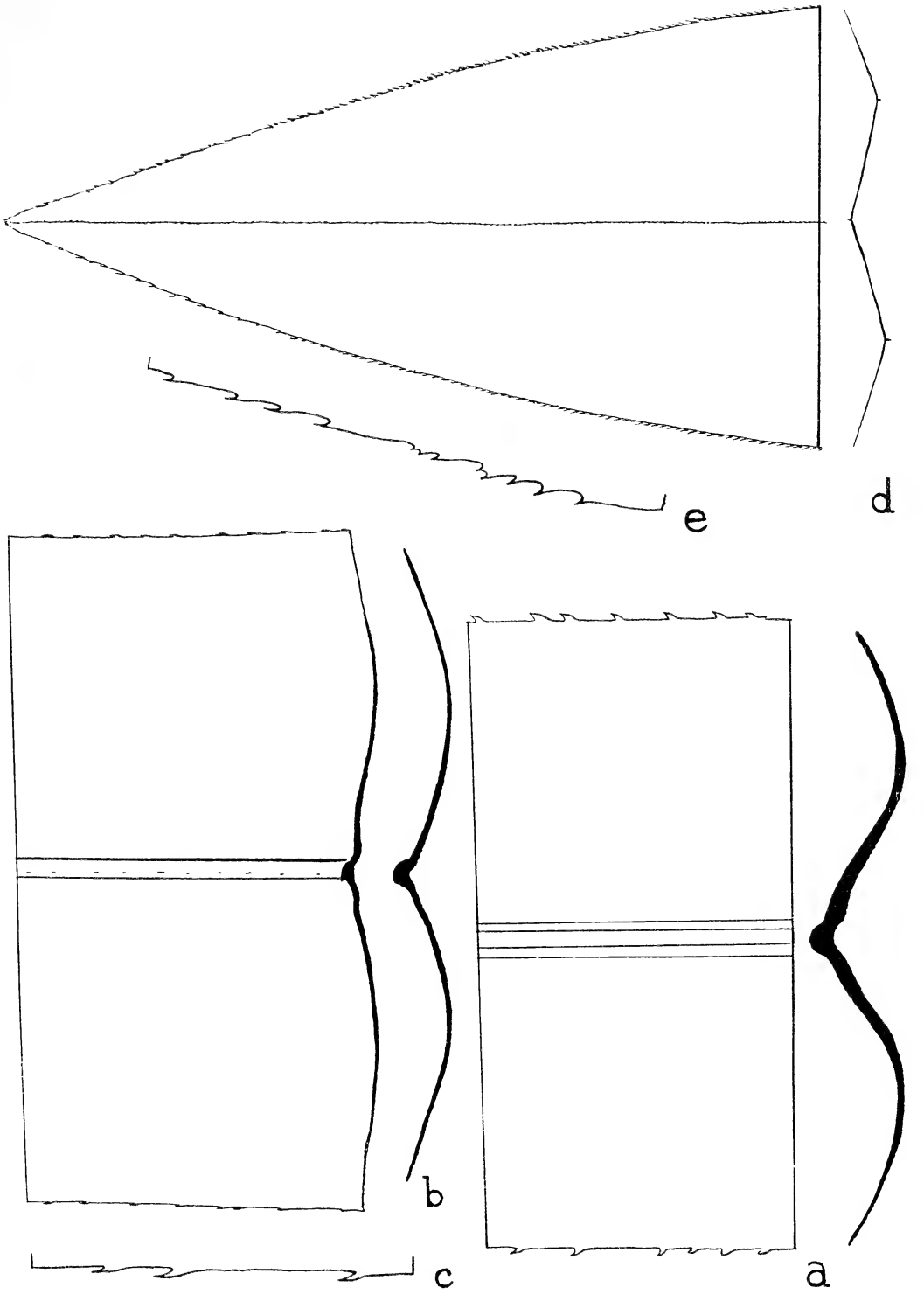

FIG. 42. *Pandanus magnicavernosus* St. John, from holotype. *a,* Leaf base, lower side, × 1; *b,* leaf middle, lower side, × 1; *c,* leaf margin at middle, × 4; *d,* leaf apex, lower side, × 1; *e,* leaf margin near apex, × 4.

stilt roots; leaves 1.8–1.9 m. long, 9.5–10 cm. wide, pale green, glaucous beneath, midrib and basal part of leaf yellow brown," soft coriaceous, nearly flat, the midrib and two secondary ribs strong, the teeth inoffensive, the apex abruptly acute, the base slightly dilated and with a membranous unarmed margin for 25 cm., beyond that the margins with stout serrations 1.5–2 mm. long, 3–10 mm. apart, stramineous but brown tipped, the adjacent midrib unarmed; the margins at midsection with the teeth 0.5 mm. long, 2–10 mm. apart, subulate but closely appressed, the midrib below with similar but stouter and slightly shorter subulate prickles, the secondaries unarmed; near the tip the margins with subulate prickles 0.5–0.9 mm. long, 1–2 mm. apart, ascending-appressed, pale, the secondaries above scabrous with minute, irregular, ascending serrations, below the midrib crowded with ascending subulate prickles 0.3–1 mm. long; fruit on slender 3-angled peduncle 90 cm. long; syncarp solitary, pendulous, 24 cm. in diameter, globose, glaucous; phalanges 2–3 (rarely 1)-celled, numerous, 7.5–8.5 cm. long, 17–35 mm. wide, 14–21 mm. thick, wedge-shaped, 5–7-angled, fleshy, upper 1/6 free, the apex depressed conic, with 1–3 tips, several angled, apical central sinuses 1–2 mm. deep and the crease between adjacent phalanges narrow, 1 mm. deep; stigmas 1.5–2 mm. long, cordate, apical, creased, if two then centripetal, if three then the central one facing laterally, phalange sides plane; endocarp in lower third, 24–30 mm. long, bony, pale brown, the lateral walls 3–4 mm. thick; seeds 10–12 mm. long, 3–4 mm. in diameter, ellipsoid; upper mesocarp one huge cavern occupying upper half of phalange except a short apical part with longitudinal fibers and transverse medullary membranes; lower mesocarp fibrous and fleshy.

HOLOTYPUS: Solomon Islands, San Cristoval I., Star Harbour, rain forest on coastal hills, one tree seen, Oct. 28, 1932, *L. J. Brass 3,120* (BRI).

DISCUSSION: This is a striking tree, with ample leaves and huge, conspicuous fruits. It fits into the section *Mammillarisia,* but at present has no known close relatives.

The specific epithet is formed from the Latin, *magnus*, large; *cavernosus*, cavernous, in allusion to the cavernous upper mesocarp.

Feral Rabbit Populations on Pacific Islands

J. S. WATSON[1]

IN THEIR MONOGRAPH, Thompson and Worden (1956: 7–22) discuss the world distribution of the European rabbit (*Oryctolagus cuniculus* L.), but make no mention of several colonies established on islands of the tropical and subtropical Pacific. It is worth drawing attention to these both to complete the picture and because of the light they throw on the great adaptability of this species.

LAYSAN ISLAND (25° 46′ N.; 171° 49′ W.): A low, sand and coral island about 2 mi. long by 1 mi. wide, in the northern half of the Hawaiian chain. Groves of sandalwood trees, thickets of bushes, and fan palms formerly grew on the island, which supported a vast albatross rookery and five endemic species of land birds. The guano deposits of Laysan were exploited between 1892 and 1904, and the manager of the works, Mr. M. Schlemmer, introduced various breeds of domestic rabbits, including the large white domestic English rabbit, to the island in about 1903 (Dill and Bryan, 1912; E. H. Bryan, 1942). The island was later set aside as a bird sanctuary. Professor Homer R. Dill led a scientific expedition from Iowa State College to Laysan in 1911. The expedition found that although the rabbits had killed many bushes and nearly exterminated several plant species, they had on the whole done less damage than might have been expected from their numbers. The extermination of the rabbits, however, was recommended as they were likely to eat out the vegetation which would result in the disappearance of the insects on which a number of endemic bird species were dependent (Dill and Bryan, 1912). To accomplish this an expedition of four men was sent to the island for 3 months in 1912–13; unfortunately, they were inadequately equipped to deal with the problem and, although over 5,000 rabbits were shot, there were so many petrel burrows and other cover that without poison it was impossible to eliminate them in so short a time (Bailey, 1956). In 1923 the Tanager Expedition visited Laysan; the island by then had been reduced to a barren waste of sand with a few stunted trees, only 4 of the 26 species of plants recorded from the island were found (Christophersen and Caum, 1931); and there were a few hundred rabbits present. These were shot, the last ones being hunted out individually. The endemic warbler (*Acrocephalus familiaris* Rothschild) had vanished; the last three Laysan honeyeaters (*Himatione sanguinea fraithii* Rothschild) died during a sand storm while the expedition was on the island; and the Laysan rail (*Porzanula palmeri* Frohawk) died out shortly afterwards (Wetmore, 1925). Extermination of the rabbits was completed and no sign of them was seen in 1936, when the island was found to be recovered in vegetation. While circling over Laysan in an aeroplane in 1949, Bailey (1956) found that the vegetation had staged a remarkable recovery and there were concentrations of black-footed albatrosses (*Diomedea nigripes* Forster) and Laysan albatrosses (*D. immutabilis* Rothschild).

LISIANSKI ISLAND (26° N., 174° W.): Another low sand and coral island about 1¼ mi. long by ¾ mi. wide, in the Hawaiian chain, some 115 mi. west of Laysan. Rabbits from Laysan liberated there some time after their introduction on Laysan in 1903 had destroyed the vegetation by 1913, when only a few living but many dead rabbits were seen (Elschner, 1915). When the Tanager Expedition arrived in 1923 the only signs of rabbits were their bleached and weathered bones, and the vegetation was starting to come back. The rabbits, having stripped the vegetation, had apparently died of starvation (Wetmore, 1925).

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J. S. Watson died August 12, 1959, after completing the first draft of this paper. Additional information on rabbits in the Hawaiian Islands has since been obtained and included in the text.—K. Wodzicki.

ISLETS IN MAIN HAWAIIAN GROUP: According to Mr. D. N. Woodside (personal communication), rabbits were introduced to several of the small islets of volcanic origin (10 to 70 acres) lying off the islands of the main Hawaiian group at unrecorded dates before or about 1915. At present only three of the islets are populated by rabbits: Manana ("Rabbit Island") (22° N., 158° W.), off the coast of Oahu; Lehua (22° N., 160° W.), off the coast of Niihau; and Molokini (21° N., 156° W.), situated in the channel between Maui and Kahoolawe. These tuff-cone islets are rather arid, suffering summer drought and occasionally missing sufficient winter rains to alleviate the dryness. The rabbit populations are subject to violent fluctuations, "die-offs" occurring during the droughts, which perhaps enables the vegetation to survive. There are no predators on these islets. The rabbits on Lehua and Molokini appear to be a mixture of domestic breeds, being of every colour; the Manana rabbits closely resemble the American cottontail in colour and ear length and it is conceivable that these rabbits are in fact cottontails (*Sylvilagus* spp.).

PHOENIX ISLAND (4° S., 171° W.): A small coral island about ¾ mi. long in the Phoenix group. There was an American guano company working here in the late 1860's and about this time domestic rabbits were liberated (Bryan, 1942). Lister (1891) found them fairly plentiful in 1889 and they were still fairly numerous in 1924, but apparently were doing no damage to the vegetation (Bryan, 1942). A survey party, which in 1937 caught a number of rabbits there in an unsuccessful attempt to liberate them in the Gilbert Islands, found them in very poor condition, squatting and allowing themselves to be caught after running about a hundred yards. There is no fresh water on the island (Maude and Maude, 1952).

PHILLIP ISLAND: A small island about half a mile long of decomposed basalt rising to 900 ft., lying off Norfolk Island (29° S., 168° E.), originally covered with trees and thick vegetation. Pigs which were introduced at an early date destroyed much of the undergrowth and rooted up the soil, starting erosion. Rabbits were introduced subsequently (Laing, 1915) and the island thronged with them in 1865 and their principal food seemed to be the bark of trees (Brenchley, 1873). By 1912 the island was fast becoming a complete desert; there was practically no soil, only a few isolated trees; hardly a seedling was to be seen and the only grass was in clefts in the rock near the beach (Laing, 1915). Rabbits were still present in 1943 and a single tree was conspicuous in its isolation (Mr. I. L. Baumgart, personal communication).

The present situation on Phillip Island is indicated in a recent letter to Dr. K. Wodzicki from Mr. B. a'B Marsh, Agricultural Officer, Norfolk Island.

Mr. Marsh made a hurried visit to the island on 4 March 1961 and saw rabbit scratchings, droppings, and a few burrows, the last being under the roots of *Lagunaria Patersonii* and another unidentified tree. The visit, being in the middle of the day, was not well timed for seeing rabbits, but, as a very rough guess, Mr. Marsh thought there might be between two and four dozen rabbits on the island. The animals had been eating the leaves of *Lagunaria* which seemed their main food.

Vegetation consists of six Norfolk Island pines (*Araucaria excelsa*), several dozen *Lagunaria* trees, a few unidentified trees with large shiny leaves, a reed known locally as Mo-oo and a few grasses and weeds. The reed grows in a few areas of 1/10 to ½ acre, usually in flat areas where there is enough soil to retain water, but over perhaps 80 per cent of the island there is no vegetation or soil. Rabbits do not eat the reed or the unidentified trees; the latter are the only trees that appear healthy. All trees have their roots exposed to a depth of 1–6 ft.; the pine trees are not actively growing but are setting seeds; the leaves of the *Lagunaria* are confined to the main branches so that the trees look as though recovering from a fire.

The topography of the island is steep with V-shaped erosion gullies at frequent intervals; run-off of water is extremely rapid and complete and carries extraordinary quantities of solid material. The effective rainfall is probably about 5 to 10 in. per annum overall, but the steeper parts retain practically no rain; the island was quite dry only two days after heavy rain. All soil has gone except from a few flat areas and screes, and removal of rabbits will

not now alter the island except in a very minor way.

In March 1953 myxomatosis was introduced, but further introductions were abandoned due to the difficulty of landing. It is now unlikely that any further eradication work will be attempted.

DISCUSSION

These islands provide an interesting contrast. On Phoenix Island, almost on the equator, conditions must be only just within the level of tolerance for the rabbit species, and factors other than food presumably hold the population down to a level where it does not seriously affect the vegetation. Rabbits have been on Phillip Island for nearly a hundred years and must have reached a state of equilibrium with the vegetation, most of which has been destroyed, but some plant species must survive that are both resistant to rabbit grazing and yet sufficiently palatable to support the existing rabbit population. On Lisianski Island no such equilibrium was reached, and it was thought that rabbits would similarly have gone from Laysan Island had they not been exterminated (Wetmore, 1925). Presumably the rate of increase of the rabbits quickly produced a large population, and the vegetation was destroyed to such an extent that it was unable to recover in time to maintain even a greatly reduced number of rabbits. Manana, Lehua, and Molokini islets are all subject to droughts during which the rabbit populations are drastically reduced and presumably the vegetation can recover sufficiently to survive.

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Relationships of the Red-backed Voles of Japan

E. W. Jameson, Jr.[1]

Eastern Asia is particularly rich in genera and species of microtine rodents, some of which are more or less intermediate between *Microtus* on the one hand and *Clethrionomys* on the other. Where species of only these two genera are concerned, there is no problem of identity because there are differences in the color, in the structure of the palate, and in the skull in general. The age of the specimen changes strikingly the condition of the cheek teeth, in which there are some of the most important generic features. Molars of immature specimens of *Clethrionomys*, for example, are rootless, and resemble in this respect the molars of adult individuals of *Microtus*. In eastern Asia there are a number of species which resemble the species of *Clethrionomys* in the palate, which terminates in a shelf, and are like *Microtus s. str.* in having rootless molars. For these forms which combine some of the structural characteristics of *Clethrionomys* and *Microtus* there are a number of generic names. A reviewer naturally wonders if his material contains mature individuals, and this doubt has caused some disagreement as to the proper generic allocation of red-backed voles of the Far East.

The red-backed voles in Japan have been discussed by Hinton (1926), whose conclusions have been accepted by Ellerman (1941) and by Ellerman and Morrison-Scott (1951). Hinton (1926: 259–262) judged that several different forms were all based on immature specimens and placed *bedfordiae, andersoni,* and *niigatae* as synonyms of *smithi.* He very carefully explained the pitfalls in separating voles on a small series and he emphasized the early age at which voles breed (and are apparently adult). In the Japanese forms in question, the age of the specimens is of great importance because these names were proposed for individuals in which the molars are rootless, and Hinton's conclusion was that they are all immature specimens. His caution is certainly justified but can be carried to misleading extremes, for by combining several distinct forms as one, it is not difficult to show that a given character, in this case the condition of the molar roots, is indeed remarkably variable. There are remarks in Hinton's appraisal of the situation that raise some doubts as to its application to the specimens he had at hand. For example, in reference to the small vole called *smithi,* he stated (1926: 260) that the type was a young male and added that "...by accident the fifty-three specimens of the series collected in Hondo, Kiushiu, and Shikoku, by M. P. Anderson in the following year are all young too." It is possible, of course, to sample a population and obtain a series in which immature specimens predominate; but it is incredible that such an experienced collector as Anderson would have preserved 53 specimens of *smithi* from at least three widely separated localities and fail to include a single adult. Hinton added:

> Later on Mr. Anderson collected thirteen in Hokkaido. The majority of these are adult, some even old; in size, skull form, and tooth pattern they are strikingly different from the material referred by Thomas to *E.—smithii.* These were therefore described as a new species, *E. (Craseomys) bedfordiae.* But two specimens of this original series of *E. bedfordiae* are immature, and these are not distinguishable from the material upon which *E. smithii* was founded.

These two presumably immature specimens could possibly belong to *Clethrionomys rutilus,* which is not uncommon in some parts of Hokkaido; and, in this region, *rutilus* is a small bright short-tailed form somewhat like *smithii.* On the same page he dismissed the form described as *E. (C.) andersoni* with the comment, "...specimens, however, are merely large adolescents, intermediate in age between the adult material upon which *E. bedfordiae* was established and the immature material referred to

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as *E. smithii.*" Lastly, "Anderson's *E. niigatae* also has been founded upon an adolescent animal. . . ."

Apparently Hinton attached no importance to the occurrence of immature *smithi* on Kyushu, Shikoku, and Honshu, and the absence of adult *smithi* everywhere but on Hokkaido. It is surprising that he did not consider that these forms with rootless molars might actually be adults, for on the mainland of Asia and on Taiwan are genera of red-backed voles in which the molars are rootless in the adults. Hinton recognized *Eothenomys, Anteliomys,* and *Aschizomys,* genera in which the molars are rootless; but failed to suggest any similarities between *smithi* and the species of these genera.

The classification of these voles by Japanese mammalogists differs considerably from the recent presentation of Ellerman (1941) and of Ellerman and Morrison-Scott (1951). In the latter work the authors were apparently unaware of the very careful study on Japanese murid rodents by Tokuda (1941).

In his monograph, Tokuda (1941) followed Oldfield Thomas in general in the classification of the Japanese red-backed voles. He considered *smithi* as a separate species in the genus *Clethrionomys, bedfordiae* was retained as a subspecies of *Clethrionomys rufocanus,* and *andersoni* was judged to be a distinct species but closely allied to *rufocanus.* Tokuda (1941: 51) followed Hanaoka in placing *Craseomys niigatae* as a synonym of *Clethrionomys andersoni.* Tokuda did not suggest at this time that *smithi* had affinities except in the genus *Clethrionomys.*

The first to suggest a different position for *smithi* was Imaizumi (1949), who placed it in the genus *Eothenomys.* Subsequently, Tokuda (1955) presented evidence for considering *smithi* a species of *Anteliomys.* Imaizumi (1957), considering *Anteliomys* a synonym of *Eothenomys,* continued to use the latter name, and described a second species, *Eothenomys kageus,* from the northern part of Honshu.

The most recent classification of the red-backed voles in Japan is by Imaizumi (1960). In this arrangement there are *Eothenomys: smithi* and *kageus;* and three species of *Clethrionomys: rutilus, rufocanus,* and *sikotanensis;* in contrast to Tokuda, Hinton, and other recent students, Imaizumi maintained *niigatae* as a species distinct from *andersoni,* and placed both in *Aschizomys.*

During 1952 I spent 10 months in Japan and made a small collection of voles. In 1958 and 1959 I was able to trap additional specimens of all but one (*Clethrionomys sikotanensis*) of the forms of red-backed voles in Japan, and from these specimens and the excellent discussions of Tokuda and Imaizumi, it is apparent that the original descriptions of Oldfield Thomas and the recent researches of Tokuda and Imaizumi more accurately express the relationships of these voles. The work of Hinton was executed apparently with little knowledge of the geologic history of the Japanese archipelago and without the advantage of having studied these Japanese voles in the field. The arrangement given below is, in most respects, like that accepted by Japanese mammalogists today. Because of the stature of Hinton's monograph, his conclusions have been followed by European and American zoologists, and reiterated, in regard to the rodents in question, by Ellerman (1941) and Ellerman and Morrison-Scott (1951). The environmental distributions and economic importance of these voles is discussed by Ota and Jameson (in press).

GENUS *Clethrionomys* Tilesius

Originally all the red-backed voles in Japan were placed in *Clethrionomys.* The Japanese *C. rutilus mikado* exists only on the island of Hokkaido. In general appearance and in most details *rutilus* closely resembles the other species of *Clethrionomys s. str.* The skull is light with rounded contours, the palate is abnormal (differing from *Microtus*), the cheek teeth are relatively light and are rooted in the adult. The mammae are in four pairs. The species in this genus are characterized by other features but the above are sufficient to separate *rutilus* from the other species of microtine rodents in Japan.

The species *rufocanus* has long been known as a rather aberrant species of *Clethrionomys.* Miller (1898*a*: 360) treated in some detail the distinctive characters of this vole:

So divergent is the animal that it may well be questioned whether it is to be regarded as a true

Evotomys (= *Clethrionomys*). Its heavy and apparently imperfectly rooted teeth more closely resemble those of many species of typical *Microtus* than they do the weak, perfectly rooted teeth of true *Evotomys*. The relationship of the root of the lower incisor and the posterior lower molar, while not typical of either genus are clearly suggestive of *Microtus* rather than *Evotomys*. The palate structure, on the other hand, appears to agree with that of *Evotomys*.

Also, in a key to the Arctic species of red-backed voles Miller (1898*a*: 359) separated *rufocanus* by the comment: "Teeth large and heavy as in *Microtus* (never perfectly rooted?). . . ." In characterizing *rufocanus*, Hinton (1926: 245) also emphasized its approach to the species of *Microtus* and on page 215 pointed out that individuals look mature "long before the molars show the slightest sign of rooting." To distinguish *rufocanus* from the other species of *Clethrionomys* Miller (1900) created the subgenus *Craseomys* with the following characters:

Skull as strongly angular as in *Microtus*, the postorbital processes well developed; teeth relatively as large as in *Microtus*, the molar row about equal to the diastema; roots of molars developed late in life; root of posterior lower molar lying in a distinct capsule on the lingual side of incisor root.

Soon after Thomas (1905) placed the Japanese forms *bedfordiae* and *andersoni* in the subgenus *Craseomys*. Later (1907), he used *Craseomys* as a genus for *Craseomys regulus* (= *Clethrionomys rufocanus regulus*) from Korea and noted that not even the oldest in the series of 18 specimens showed any trace of roots on the molars.

Aschizomys lemminus was described as a new genus and species by Miller (1898*b*) on the basis of a single specimen and was characterized in these terms: "Palate as in *Clethrionomys*. Molars small and weak, as in *Clethrionomys*, but teeth growing from a persistent pulp as in *Microtus*) which strongly displaces root of large posterior lower molar. Plantar tubercles six. Number of mammae unknown." The illustrations accompanying the original description indicate other features common to both *lemminus* and *rufocanus:* the encapsulated roots of the upper second molar and the lower third molar and the reduced lateral tubercles on the rostrum. The upper third molar of *lemminus* is longer than in *rufocanus* and there is little doubt that the two species are separate. The third upper molar of *Clethrionomys niigatae* of northern Honshu is long and similar to *lemminus*. In the original description of *Aschizomys* Miller recommended that *rufocanus* was allied to *lemminus* and later Imaizumi (1957: 199) suggested that *Clethrionomys niigatae* might well be placed in *Aschizomys*. Also, Hinton (1926: 43) stated that *lemminus* seemed to be very close to *rufocanus*. However, as Miller suggested (1898*a*: 359), the molars of *rufocanus* form roots very late in life; it is quite possible that *rufocanus* and *lemminus* are alike in this respect as well, and that a large series of *Aschizomys lemminus* would probably contain a few individuals old enough to have partly rooted molars. Granting this supposition, a reasonable arrangement would be to place *rufocanus* with *lemminus* in *Aschizomys*.

In this case *Craseomys* Miller, 1900 will become a synonym of *Aschizomys* Miller 1898. Recent authors have regarded *Craseomys* a synonym of *Clethrionomys;* perhaps because they considered it unnecessary to retain a subgenus which contained but a single species. In placing *rufocanus, niigatae, andersoni,* and a new species from Honshu together with *lemminus* all in *Aschizomys,* one must decide the proper position of this group. Although Miller preferred to call it a genus, he did consider that *Aschizomys* could be placed with *Eothenomys* and *Anteliomys. Eothenomys* combines characters of *Microtus* and *Clethrionomys;* and *Aschizomys* (including *rufocanus* and *andersoni*) bridges the gap between *Eothenomys* and *Clethrionomys*.

As pointed out by Ellerman and Morrison-Scott (1951: 670), Russian authors place *Aschizomys* as a subgenus of *Alticola*. The two groups are certainly very close; but, if I am correct in presuming that very old specimens of *Aschizomys lemminus* will tend to develop roots on the molars, then *Aschizomys* is more appropriately placed with *Clethrionomys*.

Inasmuch as a few old individuals of *rufocanus* and *niigatae* have partly rooted molars, it seems best to place *Aschizomys* as a subgenus under *Clethrionomys,* and the forms known in Japan can be separated by the key below.

KEY TO SPECIES OF *Clethrionomys* IN JAPAN

1. Molars developing long roots in adults; postorbital crests poorly developed or absent; second upper molar and third lower molar not encapsulated in adults: (subgenus *Clethrionomys*) ..... *rutilus*

   Molars rootless except in very old adults; postorbital crests well developed; second upper molar and third lower molar usually encapsulated in adults (subgenus *Aschizomys*) 2

2. Third upper molar with three inner salient angles (Fig. 1); tail less than one-half the body length; on Hokkaido ..... *rufocanus bedfordiae*

   Third upper molar with more than three inner salient angles or loops although some projections may be irregular or rounded (Fig. 1); on Honshu 3

3. Salient angles of all cheek teeth rounded or irregular, and triangles often open (Fig. 1); auditory bullae relatively small; in low elevation evergreen broad leaved forests of extreme southern Honshu ..... *imaizumii*

   Salient angles more or less pointed, and triangles usually closed; auditory bullae relatively large; in coniferous forests of the northern half of Honshu 4

4. Rostrum relatively long; anterior palatine foramina arise from about level of anterior molar alveolae; upper molar tooth row more than 6.0 mm ..... *niigatae*

   Rostrum shorter; anterior palatine foramina arise from a point distinctly anterior to the level of anterior molar alveolae; upper molar row less than 6.0 mm ..... *andersoni*

Clethrionomys rufocanus bedfordiae (Thomas, 1905)

Evotomys bedfordiae Thomas, 1905, Abstracts, Proceedings, Zoological Society of London, no. 23. (Holotype from Shinshinotsu, near Sapporo, Hokkaido.)

This is the form of *rufocanus* which occurs on the northern island, Hokkaido. It is a large, richly colored species with a tail of moderate length. It is difficult to compare *bedfordiae* with the other named subspecies: the illustrations of *rufocanus shanseius* (of the adjacent mainland) in Hinton (1926) are made from specimens which perhaps are not *rufocanus* and may not even belong in *Clethrionomys*. Presumably the nearest relatives live on the island of Sakhalin and the adjacent mainland. *Clethrionomys sikotanensis* (Tokuda, 1935) seems to be quite distinct from, although allied to, *rufocanus; sikotanensis* is known from the Southern Kuriles and may be more closely related to *lemminus*.

The skull of *bedfordiae* resembles the illustration of *C. r. rufocanus* in Hinton (1926: fig. 80); the depicted specimen is from an unspecified locality. Hinton's illustration of *C. r. shanseius* (1926: fig. 83) is from the type series of *Caromys inez; shanseius* (from China) should be closer to *bedfordiae* than is typical *rufocanus* (from Sweden), but there is little doubt that Hinton's illustration of *shanseius* represents a form at least specifically distinct from *rufocanus*. The enamel pattern (Fig. 1) is typical of *C. r. bedfordiae* and the third upper molar is especially characteristic. In 22 adults examined, 2 have distinctly rooted molars; in 8, the pulp cavities are more or less closed off, indicating that roots would probably have formed later in life. The anterior palatine foramina are expanded anteriorly and quite narrow posteriorly and resemble *C. r. rufocanus* in this respect. The tail is less than one-half the body length.

C. rufocanus bedfordiae is the most abundant microtine mouse on Hokkaido and is almost always more common than *C. rutilus*. In the absence of any competing species of *Microtus* (which does not occur on Hokkaido), *rufocanus* is sometimes a common inhabitant of open meadows and is of considerable economic importance (Ota and Jameson, in press).

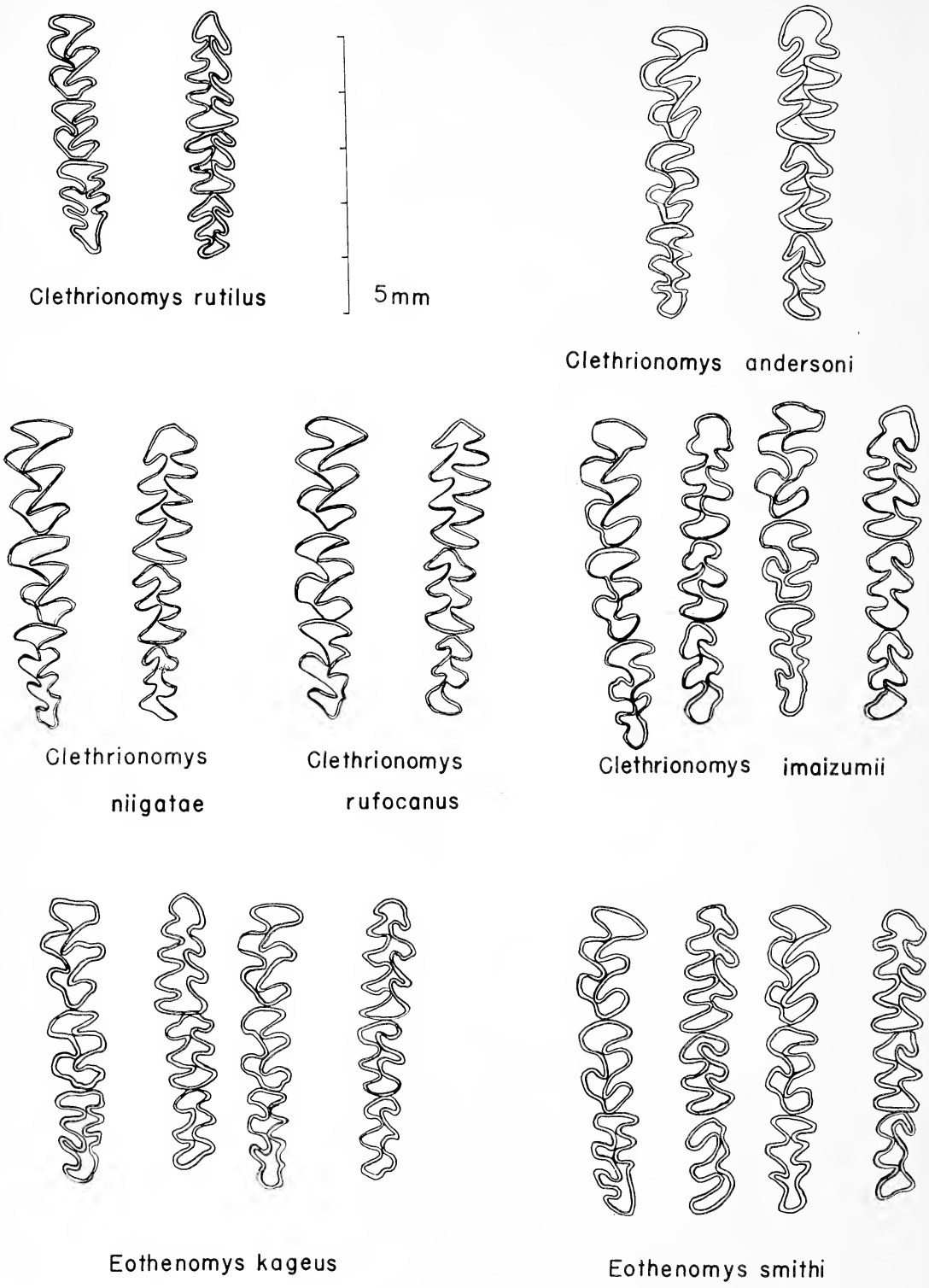

FIG. 1. Enamel patterns of Japanese red-backed voles.

Clethrionomys andersoni (Thomas, 1905)

Evotomys andersoni Thomas, 1905, Abstracts, Proceedings, Zoological Society of London, no. 28. (Holotype, from Tsunagi, Iwate-ken, Honshu.)

This form is sometimes considered to be a subspecies of *rufocanus,* to which it is closely related. *C. andersoni* is easily separable from *C. rufocanus bedfordiae* by the longer third upper molar, which has four inner salient angles. *C. andersoni* is close also to *C. niigatae,* which is sometimes considered to be the same. Examination of specimens of the type series of both *andersoni* and *niigatae* indicated that the two are distinct and that adults can be identified by the above key.

C. andersoni is an inhabitant of coniferous forests in northern Honshu, in Aomori-ken, Fukushima-ken, and Iwate-ken, according to Imaizumi (1960: 134).

Clethrionomys niigatae (Anderson, 1909)

Craseomys niigatae Anderson, 1909, The Annals and Magazine of Natural History, vol. 4, ser. 8: 317. (Holotype from Akakura, Niigata-ken, Honshu.)

For a very long period *C. niigatae* had been considered to be a synonym of *C. andersoni;* but, after studying specimens from the type series of both species, I agree with Imaizumi (1960) that the two are distinct species. In the nine adults examined, one specimen has closed pulp cavities and incipient roots. This is in contrast to the specimens examined by Imaizumi (1957 and 1960); the series in the National Science Museum in Tokyo all possess rootless molars. *C. niigatae* lives in the higher elevations of central Honshu. In Nagano-ken, it is found at approximately 1900 m. and higher among boulders both in virgin forests of fir and spruce and in rather open tangles of wild raspberries and currants.

Clethrionomys imaizumii, new species

TYPE: Adult male, skin and skull. Collected 13 Feb. 1959, Nachi Falls, 300 feet elevation, Wakayama-ken, Honshu, Japan; E. W. Jameson, Jr., no. 1083.

RANGE: Probably in broadleaved forests at low elevations in extreme southern Wakayama-ken (Kii Peninsula).

DIAGNOSIS: A rather large, brightly colored, long-tailed species of the subgenus *Aschizomys.* Dorsum Rood's Brown; venter Sayal Brown; tail bicolor, thinly haired, as in *rufocanus* and *andersoni* (color from Ridgway, 1912). Skull with rather small auditory bullae. Molars with angles rounded.

MEASUREMENTS (in mm.): Holotype (and paratype): Total length, 194 (184); tail, 67 (61); hind foot, 22 (21). Skull: condylobasilar length, 29.1 (skull of paratype damaged); zygomatic breadth, 15.6 (15.1); interorbital breadth, 4.3 (4.4); lambdoidal breadth 12.5 (—); alveolar length of upper molar row, 6.9 (6.3); diastema, 8.3 (7.7).

This species is most nearly like *C. niigatae,* but differs strikingly in the color and dentition. The molars are rootless with open dentine spaces in the two adult males seen. The enamel pattern is quite different, however: the triangles are rounded and indistinct and frequently open (Fig. 1). The auditory bullae are markedly smaller.

This species inhabits the luxuriant hardwood forests of the southern part of the Kii Peninsula in Wakayama-ken, the southernmost part of Honshu. Specimens were first collected by Dr. R. Kano; and Dr. Yoshinori Imaizumi kindly directed me to collecting localities.

These four forms of the subgenus *Aschizomys* are separable on external characters, and these features are substantiated by constant dental and other cranial morphology. The relative proportions of the tail and body lengths are rather different for *rufocanus,* on the one hand, and for *andersoni, niigatae,* and *imaizumii* on the other hand. *C. niigatae* and *C. imaizumii* are long tailed. In nine specimens of *niigatae* from the upper slopes of Yatsugatake, the tail is from 58 to 66 mm. in actual length, and the tail length is from 51 to 62 per cent of the body length. In a series of 22 adults of *C. rufocanus bedfordiae* from various localities in Hokkaido, the tail is from 34 to 56 mm., and the tail length is from 28 to 46 per cent of the body length. It is quite possible that large series of both species would show some

overlap in this character but the difference is nevertheless real and fairly constant. *C. imaizumii* is a long-tailed animal like *niigatae*. The general fascies of the enamel patterns of *C. rufocanus bedfordiae, C. niigatae,* and *C. andersoni* are angular (Fig. 1), but *andersoni* and *niigatae* are distinct in having four inner salient angles in the third upper molar, whereas *rufocanus bedfordiae* has three. The enamel pattern of *imaizumii* is quite different in having the angles rounded, and there is a tendency for the loops and triangles to remain open (Fig. 1). The four species differ also in the form of the anterior palatine foramina. The hind foot of *rufocanus bedfordiae* is more densely furred than that of *niigatae, imaizumii,* and *andersoni,* but all species are alike in possessing six plantar tubercles between which there are tiny projections.

Imaizumi (1957) intimated that *niigatae* might be generically distinct from *rufocanus bedfordiae* because the molars are rarely rooted in *bedfordiae* and seemed never to be rooted in *niigatae*. In one specimen of *niigatae* examined by me, the pulp cavities are closed and there are incipient roots. Later (1960) Imaizumi placed *niigatae* and *andersoni* in *Aschizomys* and kept *rufocanus* in *Clethrionomys*; but such an arrangement does not indicate the nearness of these three species. As will be pointed out later in this paper, *andersoni* and *niigatae* almost certainly emigrated from Hokkaido from a stock close to *rufocanus*. Imaizumi's suggestion, reasonable as it may seem, simply emphasizes the weakness of the presence or absence of molar roots as a generic character in this case.

Clethrionomys rutilus mikado (Thomas, 1905)

Evotomys mikado Thomas, 1905, Abstract, Proceedings, Zoological Society of London, no. 23, p. 19. (Holotype from Aoyama, Hokkaido.)

This bright red little vole is quite unlike any other species in Japan. The color, rounded enamel pattern (Fig. 1), well-developed molar roots, and small size separate *rutilus* from *rufocanus,* the only other vole in Hokkaido. The molar row is rather short, as in *Eothenomys smithi* and *E. kageus,* and the enamel patterns are similar, but the angles are less rounded. In *C. rutilus* there are four pairs of mammae. One specimen was examined.

C. rutilus mikado is a rather uncommon dweller of the forests of Hokkaido and is not known to occur elsewhere in Japan.

GENUS *Eothenomys* Miller

The other genus of red-backed voles in Japan is *Eothenomys*; most of the species occur in China and one (*melanogaster*, the type of the genus) is found also on Taiwan. These species are quite close to *Clethrionomys* in general and some of them are perhaps related to the species of the subgenus *Aschizomys* in particular. In *Eothenomys* the color is highly variable, but some species are reddish and so resemble the species of *Clethrionomys,* with which they have been confused on more than one occasion. *Eothenomys* differs in possessing rootless molars and only two or three pairs of mammae. Even in the oldest specimens there is no closure of the pulp cavities. The skull of *Eothenomys* is light and delicate and tends to be rounded; and the palate terminates in a shelf, as in *Clethrionomys.*

KEY TO SPECIES OF *Eothenomys* IN JAPAN

1. Mammae four.....*kageus*
   Mammae six.....*smithi*

Eothenomys smithi (Thomas, 1905)

Evotomys smithi Thomas, 1905, Annals and Magazine of Natural History, series 7, vol. 15, p. 493. (Holotype from Kobe, Honshu.)

In Japan, the species *smithi* was described from specimens from Kobe, on the island of Honshu; *smithi* is also a common species on Shikoku and Kyushu, and a shorter-tailed subspecies (*okiensis*) was described from the island of Dogo in the Oki Group. The species *smithi* was described by Thomas in 1905, who at that time placed it in *Evotomys* (= *Clethrionomys*); and, noting some differences from the morphology of most species of that genus, he erected the subgenus *Phaulomys.* Thomas stated then that *smithi* showed characters of *Evotomys, Eothenomys,* and *Anteliomys.* Externally *smithi* is similar to species of *Clethrionomys,* except that there are two or three pairs of mammae

instead of four pairs. The form of the skull resembles that of *C. rutilus* and the other species of *Clethrionomys s. str.* (not including *rufocanus, andersoni, imaizumii,* and *niigatae*): the skull is delicate and rounded and the postorbital projections are barely developed. The enamel pattern tends to be rounded rather than angular; Thomas noted that the closed triangles tend to be little broader than long (Fig. 1). *Phaulomys* stands apart from *Clethrionomys* because the molars are rootless in the adult. Thomas also pointed out the encapsulated root of the second upper molar which projects into the orbital fossa; this invariably occurs in microtine rodents when the molars are not rooted and is simply another way of stating this condition. Since the description of *smithi,* many hundred of specimens have been collected and the molars are known to be rootless even in old adults. (Hinton's [1926] observation to the contrary resulted from his confusing *Clethrionomys rufocanus bedfordiae* and perhaps *C. rutilus mikado* with *smithi.*) Recent studies by Japanese workers (e.g., Tokuda, 1955, and Imaizumi, 1957) indicated that *smithi* is allied to the Chinese species of *Anteliomys* (a synonym or subgenus of *Eothenomys*), and the proper name for this species is *Eothenomys smithi.* Nineteen specimens were examined.

Eothenomys kageus Imaizumi, 1957

Eothenomys kageus Imaizumi, 1957, Bulletin, National Science Museum (Tokyo), vol. 3, no. 3, p. 204. (Holotype from Yamuramachi, Minamitsuru-gun, Yamanashi-ken, Honshu.)

Imaizumi (1957) named the form from the northeastern part of Honshu as *E. kageus.* From the detailed description of *kageus,* it is apparent that *kageus* and *smithi* are very close. *E. kageus* has two pairs of mammae whereas in *smithi* there are three pairs. The size, color, and body measurements of *E. kageus* are very close to those of *E. smithi.* The enamel patterns of the two species are also very similar (Fig. 1). The original description of *E. kageus* included a difference in the posterior angle of the zygomatic arch; but the explanatory drawing (Imaizumi, 1957: fig. 3) indicated that the angle measured on *E. kageus* was different from that taken from *E. smithi,* and the data are not comparable. The differences in the bacula of *E. kageus* and *E. smithi* may be due to individual variation: specimens of both species are extremely variable and there seem to be no constant differences in the bacula of the two named forms (Fig. 2). Six specimens were examined. Future studies may reveal that *E. kageus* is a subspecies of *E. smithi.*

Eothenomys smithi and *E. kageus* are similar in habits and habitat. They dwell in forested regions from sea level to elevations of 2500 m. or more, but generally do not occur together with *Clethrionomys niigatae, imaizumii,* or *andersoni.* On Yatsugatake, *E. kageus* occurs up to about 2000 m., above which level *C. niigatae* is found; but on the eastern slope of Ontake, where *C. niigatae* does not occur, *E. smithi* extends well above 2000 m. (Tokuda, 1950); and on Mt. Fuji (where *C. niigatae* is absent) *E. kageus* is found to the upper limit of the forest (Imaizumi, 1944). On Kyushu, *E. smithi* is the only red-backed vole, and it lives in wooded areas from at or near sea level to the highest peaks, becoming more abundant at the higher elevations. On Shikoku, where *Microtus montebelloi* is not found, *E. smithi* may move from the forest to relatively open grassy or brushy areas (Ota and Jameson, in press). *Eothenomys* does not occur on Hokkaido.

The bacula of the red-backed voles in Japan (Fig. 2) are rather variable within a given species, and provide rather poor taxonomic characters at the specific level. Some of the smaller bacula are obviously from young animals but even examples of the same size may be remarkably dissimilar. There are differences in both size and shape of the shaft and its base as well as in the three prongs. There seem to be no distinctions between the bacula of *Eothenomys kageus* and *E. smithi* unless the shaft in *kageus* is slightly more slender. There are probably no differences between the bacula of *Clethrionomys niigatae* and *C. rufocanus bedfordiae,* but *C. imaizumii* has relatively larger prongs which are rather divergent, and in this respect resembles those of some species of *Microtus.* Most bacula of these voles have a slight keel on the median tyne, a character of the bacula of both *Clethrionomys* and *Microtus.* No bacula of *C. andersoni* were available.

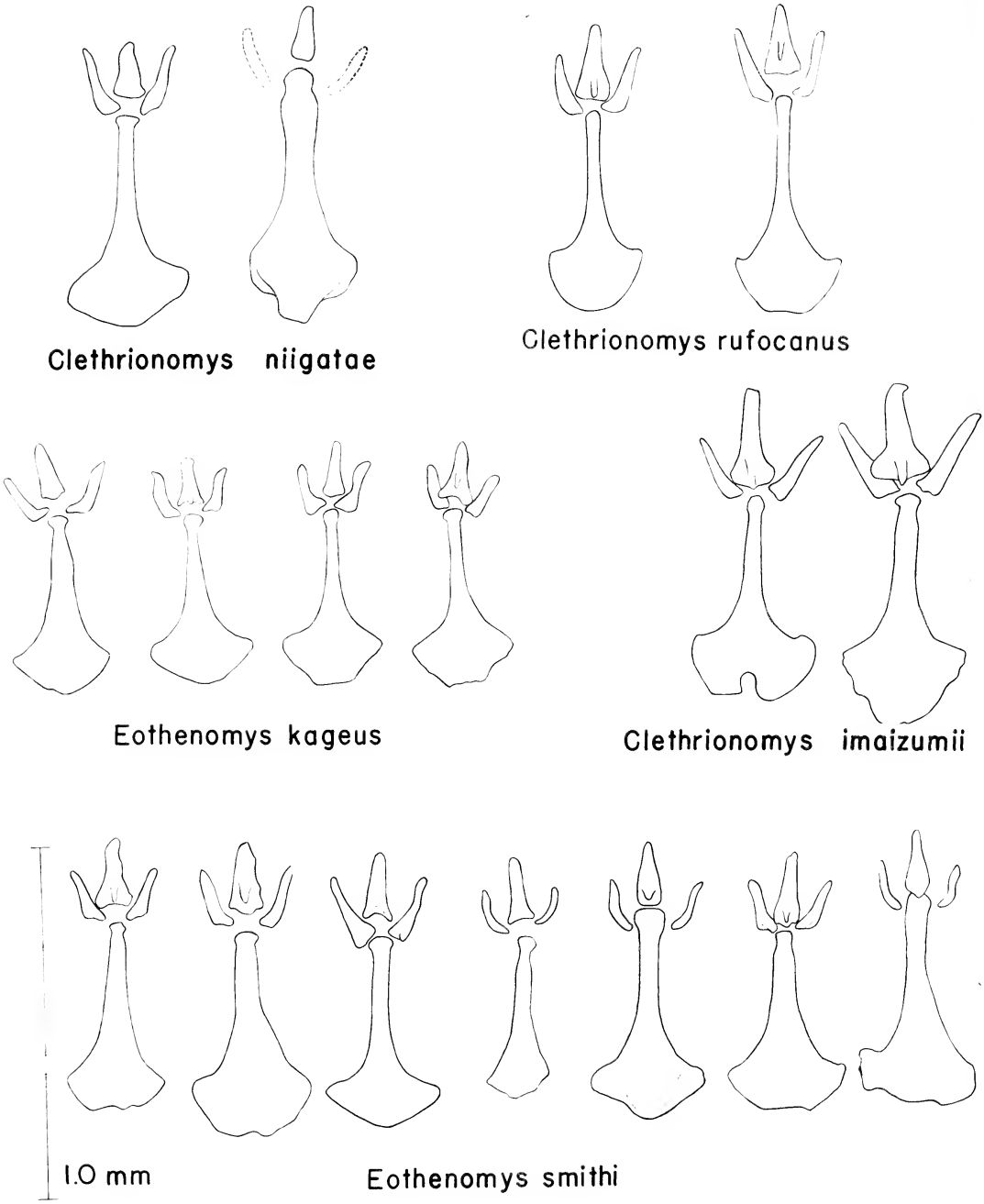

FIG. 2. Bacula of Japanese species of *Eothenomys* and *Clethrionomys* (*Aschizomys*).

GEOGRAPHIC ORIGIN OF RED-BACKED VOLES IN JAPAN

In the Pleistocene and earlier the present archipelago of Japan was connected to the mainland in the south, between Kyushu and the Korean Peninsula, and in the north, between Hokkaido, Sakhalin, and adjacent Siberia. At approximately the same time, changes resulted in the separation of Kyushu and Korea, and also the formation of the Tsugaru Strait between Hokkaido and Honshu. Consequently, the islands of Kyushu, Shikoku, and Honshu no longer received immigrants from the continent, and they were isolated from the effects of faunal movements on the mainland. Today, the fauna of the old islands of Kyushu, Shikoku, and Honshu is, in many respects, quite different from that of the immediately adjacent mainland, and has its closest affinities to the southwest in China. This faunal difference has been mentioned as early as Thomas' 1905 paper. On the other hand, Hokkaido and Sakhalin remained part of the mainland and were subjected to the faunal changes that affected southeastern Siberia and Korea. There are no land mammals in Hokkaido that are more than subspecifically distinct from those of nearby Siberia and Korea. The important and extensive movements of mammals in this general area during the Pleistocene (see Simpson, 1947: 643) changed the fauna of Hokkaido, replacing with more recent forms the original fauna that now remains in the older Japanese islands.

Eothenomys smithi probably entered Japan on the old route between Korea and Kyushu via a connection which remains today as the islands of Tsushima and Iki. *E. smithi* moved on from Kyushu to Shikoku and is now the only microtine rodent known from the latter island. This vole moved also to Honshu and now occupies a large part of that island, at least to southern Nagano-ken. *E. smithi,* or its progenitor, at one time must have occurred in Korea although the genus is not there now. *E. kageus* may have come from the north via Sakhalin and Hokkaido, although its occurrence is now confined to the northern half of Honshu south to where it abuts the geographic range of *E. smithi.* The changes which resulted in the extinction or the emigration of *Eothenomys* from Korea and Siberia apparently affected Hokkaido as well. Actually, it seems likely that *E. smithi* and *E. kageus* are offshoots from a single ancestor which differentiated slightly along the coast from Korea to Siberia so that different subspecies entered Kyushu and Hokkaido. This could account for the great similarity between these two forms that now occupy adjacent but not overlapping geographic areas.

Similarly, the species of *Clethrionomys* came to Japan by two routes. *C. imaizumii,* which is now known only from the low elevations of Wakayama-ken, may have its relatives among one of the many kinds of red-backed voles described from China. This is conjecture, but this vole is now associated with a semitropical flora of broad-leaved hardwoods. This species, moreover, is morphologically quite distinct from *C. andersoni, C. niigatae,* and *C. rufocanus bedfordiae,* which are found in forests of fir (*Abies* spp.) and spruce (*Picea* spp.). *C. niigatae* and *C. andersoni* are almost certainly arrivals via Hokkaido. Although *niigatae* and *andersoni* are close relatives of *C. rufocanus bedfordiae,* they may have been derived from an earlier stock. Hokkaido and Honshu were separated since before the Pleistocene, and *niigatae* and *andersoni* were immune to the immigrants of *C. rufocanus bedfordiae.* Not only are the three species close morphologically, but they share three species of fleas which are parasites of *C. rufocanus* in Hokkaido: *Catallagia striata, Megabothris sokolovi,* and *Rhadinopsylla alphabetica.* One (*Catallagia striata*) occurs also in Siberia and another (*Megabothris sokolovi*) in the Kuriles.

The occurrence of *C. rutilus* needs little explanation. It is obviously a rather recent arrival in Hokkaido. If it ever extended to Honshu, it did not persist, and it may well have entered Japan after the separation of Hokkaido from Honshu.

SUMMARY

There are seven species of red-backed voles in Japan. *Clethrionomys* (*Clethrionomys*) *rutilus* occurs in Hokkaido. The species *andersoni, niigatae,* and *imaizumii* (from Honshu) and *rufocanus* (from Hokkaido) are considered to represent *Aschizomys,* which is placed as a subgenus of *Clethrionomys. Eothenomys smithi* in-

habits Kyushu, Shikoku, and Honshu, and *E. kageus* occupies the northern half of Honshu.

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Two Shark Incidents at Eniwetok Atoll, Marshall Islands[1]

E. S. Hobson,[2] F. Mautin,[3] and E. S. Reese[2]

The two shark incidents described in this paper can be be considered as unprovoked shark attacks (Gilbert *et al.* 1960: 324). The importance of documenting these incidents is that they were observed by persons with some experience in the study of animal behavior. The great need of precise and detailed observational information on shark attacks has been stressed in recent reports on the subject (Coppleson, 1958: ix; Gilbert *et al.,* 1960: 323; Tester, 1960: 181). It is the belief of the authors that well-documented reports of shark incidents will contribute significantly to a clearer understanding of the stimulus situations in which shark attacks on man can be expected.

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FIRST INCIDENT

At noon on September 1, 1960, Hobson, Mautin, and Reese were engaged in spear fishing activities on a reef about 25 ft. below the surface and approximately 200 yd. from shore on the lagoon side of Parry Island, Eniwetok Atoll, Marshall Islands. Dr. Richard A. Boolootian of the University of California was in a 16-ft. skiff powered by a 35-hp. outboard motor which was idling nearby. The sea was calm, there was very little wind, and the sky was clear. Underwater visibility was in excess of 100 ft. Table 1 indicates the nature of the equipment that was being used. The spatial relationship of the divers to one another and to the skiff above the reef at the start and the end of the encounter is shown in Figure 1.

Hobson speared a 25-lb. grouper (*Plectropomus* sp.), which swam, trailing the spear, beneath a large coral boulder (rock 1, Fig. 1). Almost immediately three grey sharks (*Carcharhinus menisorrah,* Fig. 2), approximately 5–7 ft. in length, appeared from the deep water of the lagoon and began to circle the rock. Hobson observed (1) the sharks were swimming in an excited manner, and (2) they paid no attention to him floating quietly on the surface. Suddenly the grouper broke cover and dashed to a second large coral boulder (rock 2, Fig. 1). The three sharks immediately followed and began to circle the second rock.

Reese, who was directly above rock 2, noticed the sharks and was also impressed with the excited appearance of their swimming. Meanwhile, Hobson swam towards rock 2 to inform Mautin and Reese of the speared fish and the excited sharks in the area. At about this time Mautin observed the sharks and noted their excited state. All three began to swim toward the skiff, making a conscious effort not to produce an undue amount of commotion on the surface. There were now four or five sharks swimming in an excited manner on the reef below. Mautin, who was unarmed and farthest from the boat, was swimming strongly in an effort to join the others. Both Hobson and Reese observed that Mautin's swim-fins were breaking the surface of the water resulting in clouds of bubbles being carried beneath the surface at each down stroke.

The following sequence of events was very rapid. Almost simultaneously with the above observation, Mautin had reached a position almost above rock 2 (see Fig. 1). Suddenly one of the sharks rose from the bottom and swam very fast in a direct line towards Mautin. Mautin saw the approaching shark and rolled on his right side

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TABLE 1

PHYSICAL CHARACTERISTICS OF DIVERS AND NATURE OF EQUIPMENT USED AT TIME OF FIRST INCIDENT

	HOBSON[1]	MAUTIN	REESE
Weight	180	195	175
Height	5′ 10″	6′ 3″	5′ 9″
Skin color	brown	brown	brown
Bathing suit	khaki	none	gray & white
Swim fins	light blue	yellow	black
Mask	dark blue	white	dark blue
Snorkel	green	white	black
Spear	Hawaiian sling with 6-ft. free shaft	none	Hawaiian sling with 6-ft. free shaft

[1] Same equipment in second incident.

in order to face the onrushing shark. When the shark was very close he kicked it violently on the snout with his swim-fins. The shark veered away, circled once or twice behind Mautin and, upon the approach of Hobson and Reese, swam away. All three swimmers were now quiet in the water.

Immediately after the first shark left the bottom, a second shark began to swim toward the surface on the same course as the first shark. However, after approaching approximately halfway, it returned to the reef floor. It is suggested that the cessation of commotion on the surface

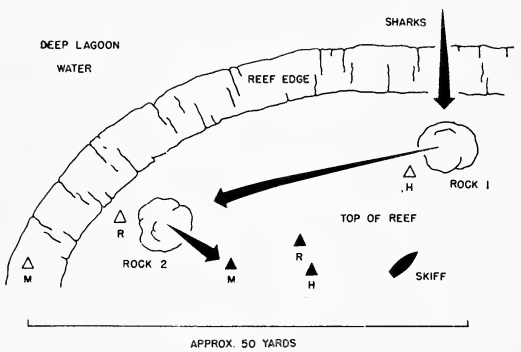

FIG. 1. Spatial relationship of divers to one another and to skiff above the coral reef at start of incident (white triangles) and at time of shark attack (black triangles). Letters beside triangles refer to diver which they represent, H = Hobson, M = Mautin, and R = Reese. Arrows indicate direction of movement of sharks.

and the presence of three swimmers resulted in the first shark swimming away and the second shark returning to the bottom.

Both Hobson and Reese were approximately 20–30 ft. from Mautin at the time the first shark attacked; however, there was no indication that the shark directed any attention toward them. It appeared that the shark was orienting to the agitation at the water's surface caused by Mautin's strong swimming. This observation supports the suggestion by Tester (1960: 183) and others that sharks are attracted by unusual commotion. A second possibility is that the shark was attracted to the bright yellow swim-fins which Mautin was wearing, but Hobson, on the basis of unpublished data, feels that this is unlikely.

Mautin gained the impression that the shark came for him believing he was the wounded fish, and that competition from the other sharks resulted in the direct and swift attack not prefaced by the usual cautious investigation.

The four to five sharks were still swimming in the same excited manner in the vicinity of rock 2 when the divers left the water.

SECOND INCIDENT

A second incident occurred the following day, September 2. Again the time was approximately noon, the sky was clear, and the surface of the lagoon was calm with underwater visibility in excess of 100 ft. Fish were being speared in shallow water along the beach at Sand Island adjacent to the deep water channel leading into the lagoon from the east. Hobson was in the water, and John C. Kay, a graduate student at the University of Hawaii, was standing off the beach in a 16-ft. skiff with the outboard motor idling. Hobson speared a 10-lb. parrot fish (Scaridae) which carried the spear shaft toward deeper water. About 35 yd. from the beach, at the edge of the reef, the bottom drops abruptly from approximately 15 ft. to over 100 ft. Grey sharks are common along this drop off. Hobson pursued the fish along the bottom, thus avoiding the surface commotion which had apparently attracted the attention of the sharks the day before. He overtook the injured fish on the bottom at a depth of approximately 15 ft. on the edge of the drop off. When the trailing spear

shaft was grasped, the fish struggled free. At the same instant a 6-ft. grey shark (*Carcharhinus menisorrah*) was upon Hobson, swimming at a slightly upward inclination directly at his face. The mouth of the shark was open, and movement of the jaws was distinctly recalled. Instinctively Hobson projected his right arm, catching the onrushing shark under the head. This, combined with a twisting, ducking motion, diverted the shark's forward rush over Hobson's left shoulder. The shark turned abruptly and circled so close that the spear which was still in the left hand could not be brought into play. As the shark circled, Hobson turned with it, pushing it away several times with his open hand until the shark was circling at a distance of approximately 4 ft.—enough room to bring the spear into use. The blunt end, which happened to be the end toward the shark, was used as a prod, and after a few jabs the shark opened its circle to approximately 10 ft. The shark appeared to be rapidly losing its aggressiveness. It seemed that apprehension toward the diver was now displacing the attack response which had asserted itself seconds before. As the boat approached, the shark fled into the adjacent deep water. The entire incident lasted only a few seconds and took place entirely on the bottom.

The shark was recognized by a deformation of the dorsal fin as one which had been involved in many of the behavior experiments conducted during the summer. It was, therefore, very familiar with the sight of humans in the water. There had been no apparent hesitation involved in its attack. Presumably its approach was made from deep water, coming over the edge of the reef which was within 10 ft. of the attack site. An approach from any other direction would have been observed.

Although the use of bare hands in warding off a shark has generally been discouraged (Gilbert *et al.,* 1960: 326), this was the only recourse in the present situation. The effectiveness of the hands in this case was no doubt largely due to the relatively small size of the shark. No lacerations of the hands occurred.

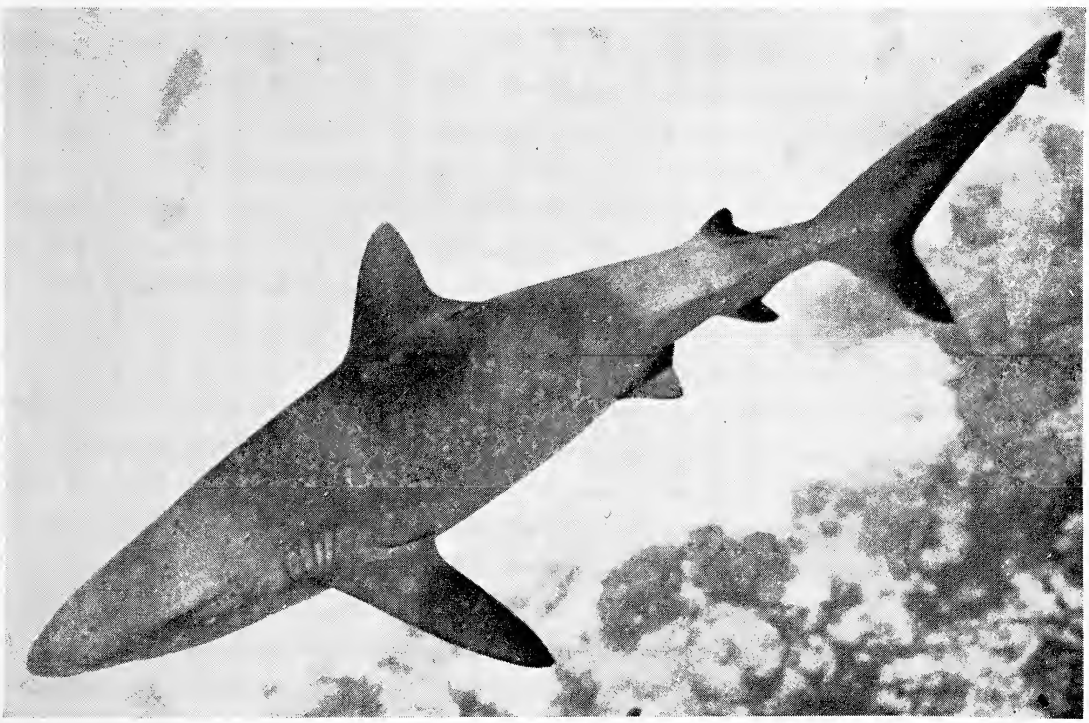

FIG. 2. *Carcharhinus menisorrah,* the species which was involved in both incidents, is common in the lagoons of most Pacific atolls, attaining a length of about 7 ft. (Photo: E. Hobson.)

TABLE 2

SUMMARY OF SIMILARITIES AND DIFFERENCES BETWEEN THE TWO INCIDENTS

	FIRST INCIDENT	SECOND INCIDENT
Activities at time of incident	spear fishing	spear fishing
Dead or injured fish present	yes: 1	yes: 1
Skin diving or SCUBA	skin diving	skin diving
Species of shark	*Carcharhinus menisorrah*	*Carcharhinus menisorrah*
Number of sharks in area	3–5	1
Size of sharks (length)	5–7 ft.	6 ft.
Date	Sep. 1, 1960	Sep. 2, 1960
Time of day	approx. noon	approx. noon
Condition of sky	clear, few clouds	clear, few clouds
Condition of sea	calm	calm
Location of incident	lagoon, Eniwetok	lagoon, Eniwetok
Distance from shore	200 yd.	35 yd.
Near deep water	yes	yes
Underwater visibility	100 ft. +	100 ft. +
Depth of water	25 ft.	15 ft.
Depth at which incident occurred	surface	15 ft., bottom
Water temperature	approx. 85° F.	approx. 85° F.
Nature of bottom	coral reef	coral reef
Number of persons in water	3	1
Nature of approach	direct, fast	direct, fast
Area of body approached	feet	head
Persistency of shark	moderate	considerable

DISCUSSION

The two incidents are summarized in Table 2. The authors believe that neither the coloration of the swimmer's equipment, the condition of the water, nor the time and nature of the day are significant. There are four major differences between the two incidents which are believed to be significant: (1) the number and relative positions of persons in the water, (2) the number of sharks in the vicinity, (3) the site of the incidents, the first on the surface, the second on the bottom, and (4) the location of the diver relative to the wounded fish. There are three major similarities between the two incidents which are believed to be significant: (1) both occurred in the vicinity of, and subsequent to, the spearing of a fish; (2) both occurred near deep water; and (3) both involved the same species of shark, which attacked without hesitation.

The last point may be explained by two facts. First, throughout the summer, Hobson, Mautin, and others noticed that *C. menisorrah* was a far more aggressive shark than the other two species which are common in the lagoon (*C. melanopterus* and *Triaenodon obesus*). This view is supported by Harry (1953: 48), who reports that the natives of the Tuamotus fear this species and claim it will attack man. Second, both incidents occurred within approximately a mile of where shark behavior experiments were conducted throughout the summer. Hobson recognized the shark in the second incident as having been a participant in these experiments, and it is probable that the sharks involved in the first incident had also had considerable experience with seeing human beings in the water. It is the belief of Hobson, Mautin, and others that the sharks became progressively bolder towards humans during the course of the summer. Thus it may be significant that both incidents occurred at the end of the summer.

It appears that one can generalize to this extent. Some species of sharks, for example *C. menisorrah,* are attracted to an area where there are injured fish. Apparently stimuli originating with the injured fish release an excited, highly motivated pattern of exploratory behavior in the shark. At such times many sharks seem to be particularly reactive to any unnatural disturbances created by humans in the general area.

This was illustrated by the response to the commotion at the surface of the water in the first incident. Furthermore, it seems they may also attack a human simply because he is located in an area of high concentration of the postulated stimulating factor, such as occurred in the second incident. In both incidents, visually directed thrusts at the sharks using hands, feet, or spear proved effective in momentarily warding off the attacking shark. Eibl-Eibesfeldt and Hass (1959: 746) and others have also noted the effectiveness of a pointed shaft as a shark deterrent.

CONCLUSIONS

1. Sharks may be expected to appear wherever spear-fishing activities are undertaken, particularly in those areas where aggressive species are known to occur.

2. When sharks appear under these circumstances they may attack a human located within the immediate area of the stimulating factor as well as humans associated with an unnatural amount of activity in the general area.

3. Sharks which have become familiar with the sight of humans in the water may be more likely to attack humans than those which have not.

4. The conclusion reached by others—that visually directed blows, preferably using a pointed instrument (such as a spear shaft), are effective in warding off sharks—is confirmed.

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Pandanus pistillaris in the Caroline Islands: An Example of Long-Range Oceanic Dispersal

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IN CONJUNCTION with the current revision of the genus *Pandanus* (St. John, 1960; St. John and Stone, in sched.) it seems appropriate to mention the factors of dispersal operative in the genus. Since a number of species of *Pandanus* are littoral in habitat, and because at least one (if not several) species is found on nearly every tropical atoll in the Pacific, it has rightly been assumed that oceanic dispersal of the buoyant fruits is responsible for the distribution. There is no question that throughout vast island groups in Micronesia, Melanesia, and Polynesia *Pandanus* has long been part of the indigenous vegetation. There are, in fact, some indications that oceanic dispersal accounts for the farthest limits of the genus, in West Africa at one extreme, Polynesia at the other, the Bonin Islands in the north, and Australia in the south. The actual number of species involved is not yet known, but species of section *Pandanus* (section *Keura* of earlier authors; see St. John, 1960) play a prominent role, especially in the Pacific region. Certain species of other sections of the genus also are primarily ocean-distributed (for example, *Pandanus dubius* Spreng., and *Pandanus tetrodon* (Gaud.) Balf.f.). In general, fruits of these species which are buoyant in seawater exhibit anatomical structures which are presumably adaptations to permit, or prolong, flotation. Brown (1931) has discussed the tissues present in fruits of certain Polynesian species, and uses the apt term aerenchyma to designate the light, pithy, upper mesocarp of such fruits. In addition, the seeds are encased in a highly sclerified osseous endocarp which, except for the minute apertures at either end, are nearly impervious to water. Fruits of this type are capable of remaining afloat for a considerable period. No experiments or observations seem to be available, but it would appear quite probable that a period of 6 months or 1 year in the ocean would not be an exaggerated estimate of the time in which floating fruits could be dispersed by currents.

The vast areas encompassed by some of these species or groups of species with buoyant fruits, and the considerable taxonomic difficulties encountered in the groups, have not heretofore permitted any definite observations to be made with respect to direction of dispersal. Over a period of many years, and because of numerous observations, the knowledge of the currents in the Pacific is now in a position to be of value in problems of oceanic dispersal; but when grave doubt exists as to the nature (and number) of entities involved, little can be said except the obvious, that *Pandanus* species of littoral areas are probably ocean dispersed.

The specimen discussed below, however, because of its unique character, is a reasonably accurate indication of one route of oceanic dispersal. Because it represents a species which is a member of section *Intraobtutus* St. John, it is at once distinguishable from the widely dispersed members of section *Pandanus*.

The specimen was collected by Dr. Ryozo Kanehira, late professor at Kyushu University, Fukuoka, Japan; the label reads, "Mokil Atoll; March 12, 1937, Kanehira no. 4203; nom. vernac. "arowan." Mokil Atoll is an isolated atoll roughly 110 mi. east of Ponape, at 6° 40′ N., 159° 45′ E., consisting of three islands on a circular reef. In April 1957 the present writer visited Mokil, spending the day of the 16th botanizing on the major islet. During this period, 15 numbers of *Pandanus* were collected (all of section *Pandanus*) and many vernacular names

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of plants. The name mentioned by Kanehira "arowan," is a general term used to designate any wild (i.e., nonedible) *Pandanus* or its fruit. The word is apparently of Marshallese origin, where the preferred spelling is "edwaan" (the *d* rolled like an *rr*). The other two islets of Mokil were not seen, so there is no corroborative information regarding the Kanehira collection. There seems no reason, however, to doubt Kanehira's data, and it is assumed that the specimen is indeed from Mokil.

The specimen consists of several phalanges, or keys, of the fruit. The configuration of the carpels which, fused, make up each phalange, determine the section of the genus, and the peculiar "focussed" pattern, as pointed out by St. John (1960) in his discussion of section *Intraobtutus,* is apparent. Although somewhat smaller than Martelli's description and figure indicate, the Kanehira specimen appears to be referable to *Pandanus pistillaris* Martelli. This species, and in fact the section itself, is known only from Melanesia, specifically, from the Bismarck Archipelago. Similar species, and a closely related section (*Lateriobtutus* St. John) occur in New Guinea.

In December 1957 the author observed species of these sections—in particular, *P. pistillaris*—in their native habitats in New Ireland and New Britain. The trees are characteristic of lowland areas, although they may occur at altitudes of 300 m. or more. Frequently they are found along streams, and not uncommonly, near the coast, especially (as near Kavieng, New Ireland) on limestone. Phalanges which had fallen from these trees were occasionally seen as drift along the stream estuaries and along adjacent beaches around Kavieng and northwestern New Ireland. In this area, a considerable variation in fruit size was observed, much more than is indicated by Martelli's description; because of this, and the above factors, the Kanehira specimen, without much hesitation, can be placed as *P. pistillaris.*

If this is established, it is interesting to consider the possibilities for drift. One obstacle is our meagre knowledge of the full, natural range of *P. pistillaris;* there seems, however, to be little question that, if it is not actually endemic in the Bismarck Archipelago, it is restricted to that general area. From a study of the excellent charts provided by Schott (1939) and by Wyrtki (1957), it may be seen that a strip about 5 to 7° north of the equator and east of the 140° meridian, during both seasons of the year, is characterized by a more or less constant eastward flow, which in northern winter emanates from the Mindanao-Morotai region, and in northern summer emanates also from a strong current moving westward and slanting northward along the upper edge of the Melanesian area, but reversing its course in the Mindanao-Morotai region. The northern summer current spans a wider course along the equator, reaching nearly all of the Caroline Islands (except perhaps Palau and Yap) and proceeding possibly beyond the Marshalls. During this season, the route of a drifting object starting from New Britain or in that vicinity would be westward along the northern coast of New Guinea as far as Morotai, thereafter more or less directly eastward through Micronesia. During northern winter, counter currents forming a strong oceanic stream along the northern coast of New Guinea would prevent such a route of drift, while several minor whorl systems in the area bounded by the Admiralty Islands on the west and by the Solomons on the east would make the drift pattern irregular and unpredictable, possibly even somewhat southward. The actual number of miles and the elapsed time at sea must remain a matter of conjecture. No information is available as to the length of time over which floating phalanges may be viable; but indirect evidence (cf. Edmondson, 1941, for data on viability of coconuts after ocean flotation) appears to indicate that distances of 1,000 mi. or more are possible.

Thus it may be seen that the route of drift of an object afloat near the Bismarck Archipelago might, by the devious route outlined, terminate in Mokil Atoll or others of the Caroline Islands. Corroboration of such a route is available. Both Riesenberg (1959) and Sinoto (1960) have reported New Guinea canoe prows washed ashore in the Marshall Islands. Riesenberg (personal communication) has photographs of an entire canoe in the Marshalls which apparently drifted along this same route. Sinoto describes a New Guinea canoe prow which drifted to Nukuoro Atoll.

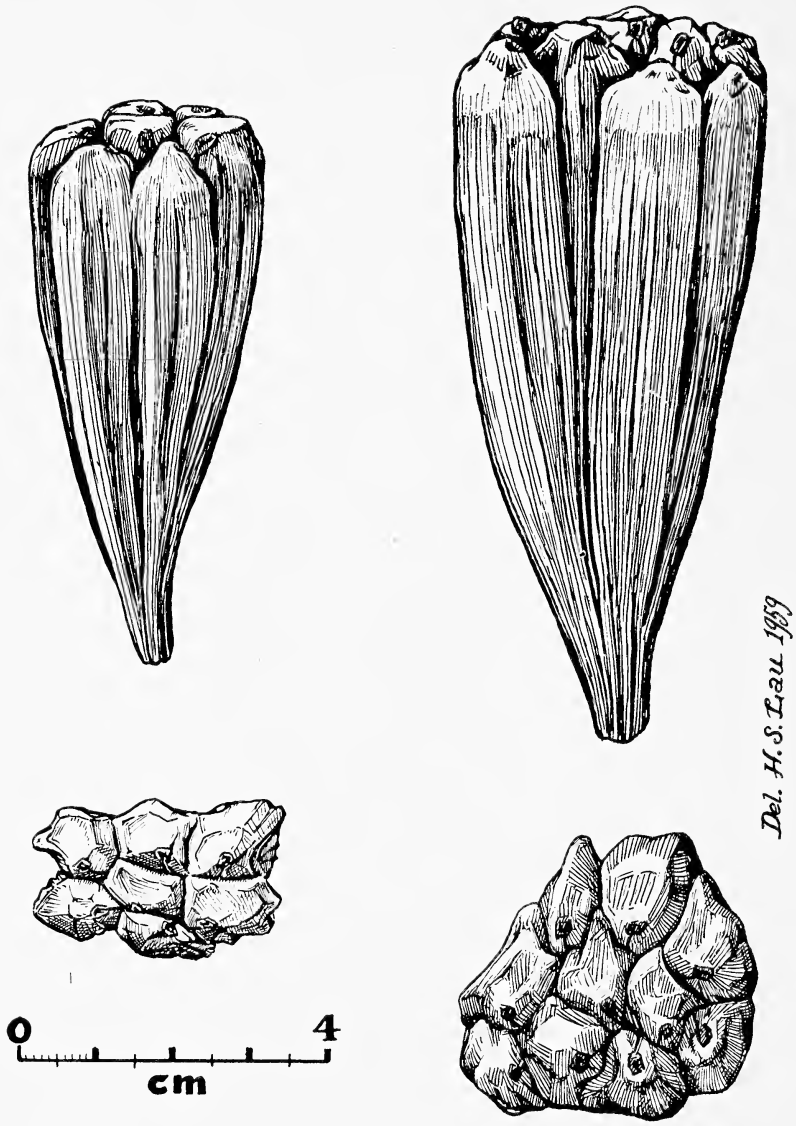

FIG. 1. *Pandanus pistillaris* Martelli. Phalanges in lateral view, natural size, and in top view. Drawn from Kanehira 4203 from Mokil Atoll, Caroline Islands.

It is postulated that the collection of *Pandanus pistillaris* in Mokil Atoll is a further example of such a route of drift. The Kanehira specimens (two of the several phalanges) are here illustrated (Fig. 1).

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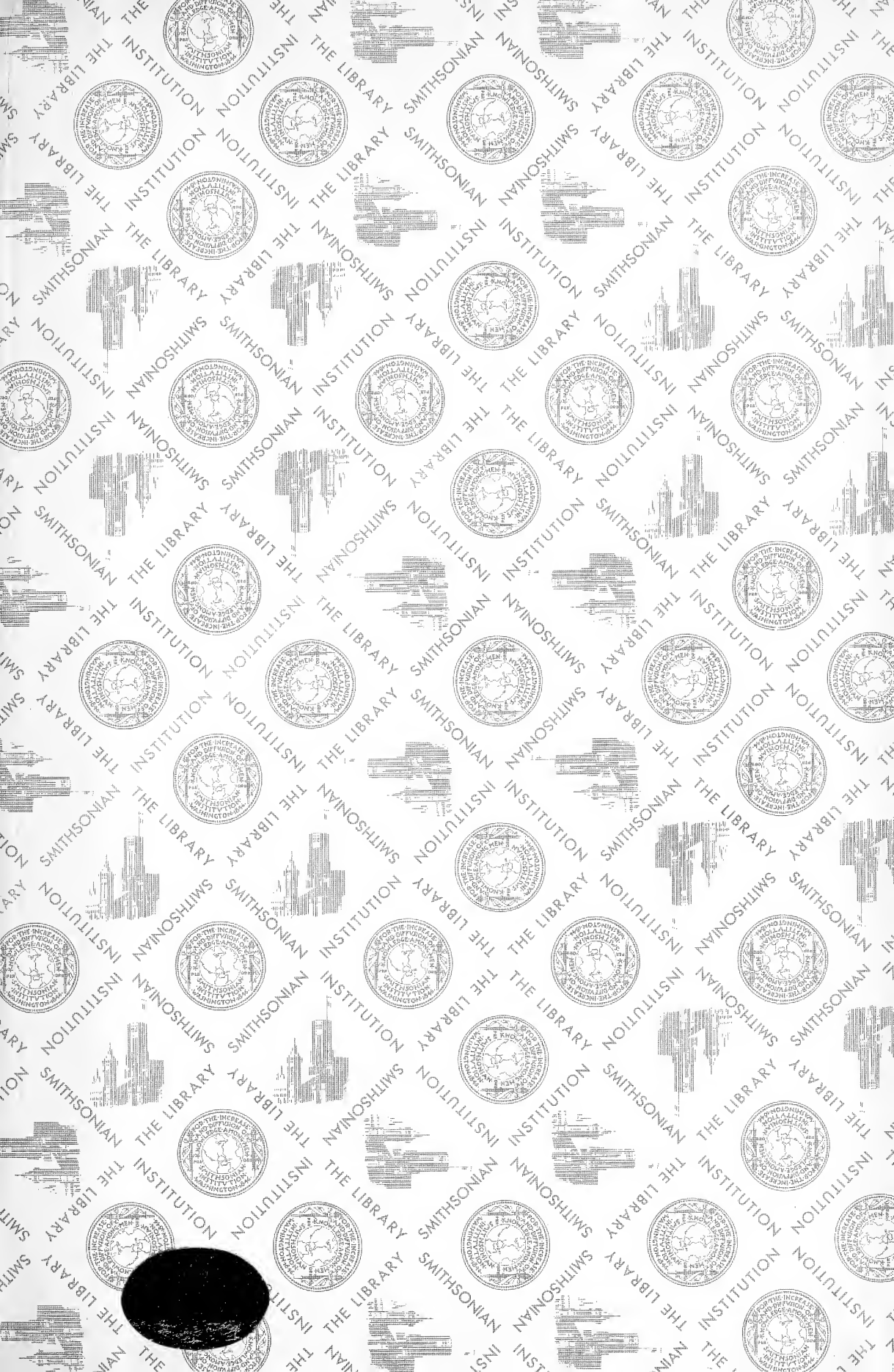
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